

**SLIDING SCALE CONTINGENCIES FOR THE HIGHWAY CONSTRUCTION  
PROJECT DEVELOPMENT PROCESS**

A Thesis

by

ADENIYI O. OLUMIDE, JR.

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

**MASTER OF SCIENCE**

December 2009

Major Subject: Civil Engineering

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Approved by:

Chair of Committee,	Stuart D. Anderson
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## **ABSTRACT**

### **Sliding Scale Contingencies for the Highway Construction Project Development Process.**

(December 2009)

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Chair of Advisory Committee: Dr. Stuart D. Anderson

In the Highway construction project development process, State Highway Agencies (SHA) prepare cost estimates for effective communication to stakeholders and for project cost control. Cost estimates prepared in the planning phase of project development typically in a time range of 10 to 20 years from project letting are characterized by a great deal of uncertainty due to low scope definition. SHAs typically include an amount as contingency in the project cost estimate to cover costs due to unidentified or unquantified risks during project development. However, most of the methods used by SHAs to apply contingency to projects lack consistency in definition and application. This leads to poor communication to stakeholders, project cost escalation and other project control issues due to inaccuracy of baseline cost estimates. This study developed a set of sliding scale contingencies for estimating contingency on highway projects taking into consideration the effect of major factors, such as project complexity that impacts contingency application.

Expert opinion was sought through the use of the Delphi technique. Experimental techniques were not suitable for this study due to the exploratory nature of the problem and the lack of data to analyze using empirical methods. The Delphi method typically consists of a series of rounds called questionnaires. Twenty-three professionals with experience in risk assessment and cost estimating agreed to participate in the study. Email was the means of communication using an excel spreadsheet. The assessment was

completed in three iterative rounds with controlled feedback to the participants on the panel at the end of each round.

Sliding scale contingencies were developed for three levels of project complexity: non-complex (minor), moderately complex, and most complex (major) projects. The sliding scale contingencies are presented as a final output of this study. This method of estimating contingency provides consistent rationale for estimating contingency. Risks are an inextricable part of the contingency estimating process. Estimators are encouraged to identify and document risks as justification for contingency values applied to a project.

## **ACKNOWLEDGEMENTS**

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## CHAPTER I

### INTRODUCTION

Construction projects vary in size, type and fundamental structural characteristics. Regardless of the differences in scope all projects require adequate planning. Thorough planning prepares stakeholders for the major risks that may be encountered during the course of a project, and enables them to meet project objectives exactly or within acceptable cost and schedule deviations from initial budgets. State Highway Agencies (SHA) estimate the cost of highway projects several times during project development so that stakeholders can make vital decisions regarding project priorities and funding. These estimates are usually associated with uncertainties that are difficult to quantify in monetary terms, and estimates developed early in the planning phase typically involve greater uncertainty than those in a later phase of project development because of a low level of scope definition. Typically, scope definition improves as a project progresses from planning through to the later phases of project development (i.e. design and construction). Ultimately, uncertainties in project estimates result in the realized cost of projects exceeding or falling below budgets. Project overruns due to this uncertainty are often hedged by including an amount as contingency in the estimates. Uncertainty can be defined as a lack of total conviction about present or future project outcomes due to a limited amount of project information.

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This thesis follows the style of *Journal of Construction Engineering and Management*.

Project risks are driven by uncertainties in the implementation of a project and some SHAs use risk to estimate contingency to include in cost estimates during project development. A risk is an uncertain event or condition that, if it occurs, has a negative or positive effect on a project's objectives (Molenaar et al. 2008). Risk assessment can be used to determine the probability of occurrence and likely impact of adverse events during a project. The estimated impact can be added to the project base estimate as contingency. There are three basic types of general contingencies in projects: tolerance in the specification; float in the schedule; and money in the budget (CIRIA 1996). Project cost contingency is an estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate (Molenaar et al. 2008). Contingency is expected to be expended during the project development and construction process. The base estimate is the most likely project estimate, exclusive of project contingency, for known costs for all known construction work (Molenaar et al. 2008). Since project uncertainties and risks are related to scope, schedule, design specifications, construction methods, materials and cost with each one having an impact on the total amount of contingency, functionally, project cost contingency may be said to include the three types of contingency defined by CIRIA to some extent.

Project cost contingency can be estimated using any of several techniques. According to Baccarini (2006) the traditional percentage method of estimating contingency is the most commonly used method in practice. However the applications of this technique vary from one organization to another depending on policies and nature of the project. In some cases percentage contingencies are entirely subjective; in other cases they are chosen within a predetermined acceptable range according to organizational policies and sometimes based on the results of a quantitative risk analysis.

## Research Background

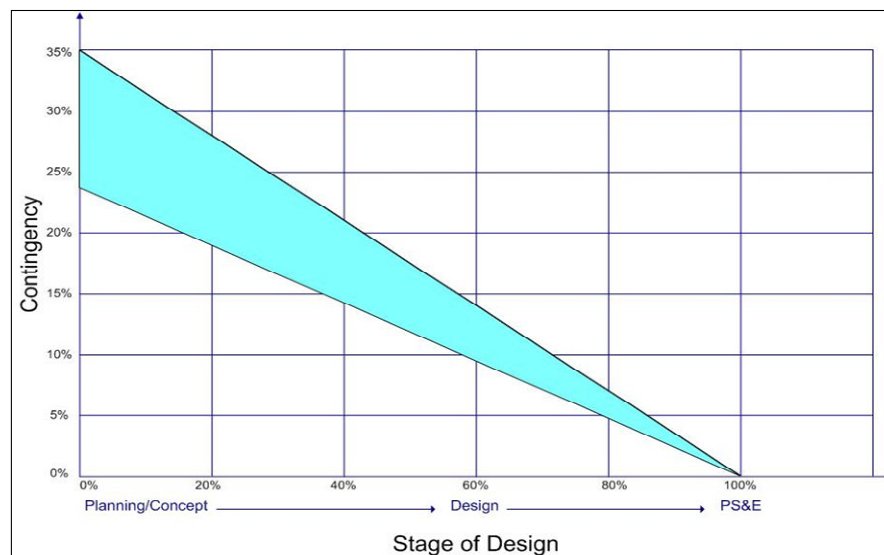
SHAs are aware that risk related issues exist for any project and therefore incorporate contingency in project estimates. Initial cost estimates are revised at various times throughout project development. They include an amount as contingency to cover issues such as high-risk elements and unforeseen site conditions. One study found that in most SHAs the application of a contingency to an estimate is so loosely defined that typically there is no consistent application of contingency (Anderson et al. 2007).

Most SHAs have a history of project costs exceeding estimated costs which causes difficulties when budgeting and possibly when payments need to be made to parties involved. Project costs exceed budget due to errors in estimating, design complexities, construction complexities, inflation, higher costs of materials and labor, unforeseen site conditions and some changes in scope. The contingency typically included by estimators is only intended to cover some of the possible causes of cost escalation.

When appropriately applied, contingency can significantly reduce the margin of error between project costs and estimated costs to within an acceptable range. This improves the accuracy of planning estimates, and enhances communication to stakeholders. A recent National Cooperative Highway Research Program (NCHRP) study *NCHRP 8-60 – Risk Analysis Tools and Management Practices to Control Transportation Project Costs* concluded that some SHAs determine appropriate ranges of contingency by performing qualitative and quantitative risk assessment techniques as standard practice. These techniques enable SHAs to more accurately determine the impact of risks should they occur and therefore allow them to add a corresponding amount of contingency to the cost estimate. Other SHAs use expert judgment, unique project contingencies or predetermined percentages. Some were found to use a combination of one or more of these methods. For instance, according to the NCHRP 8-60 study report, California, Maryland and Washington State Departments of Transportation (DOT) stated in their survey responses that they use a combination of formal risk analysis and unique project



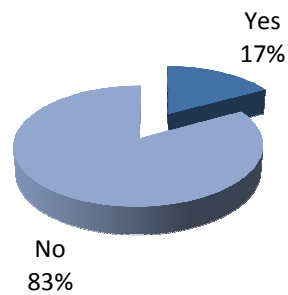
contingencies (Molenaar et al. 2008). Ohio State Department of Transportation on the other hand uses a Microsoft excel based scale that includes contingencies in project cost estimates based on different levels of design completion (Figure 1). For instance, a contingency between 19% and 28% (say 25%) may be appropriate at the Planning/Concept stage of design (20% completion) while at a later stage (say 80% design completion) a contingency of 4 to 6% would be more appropriate.



**Figure 1: Ohio DOT Design Completion Contingency Guidelines for Cost Estimating of Major Projects (NCHRP 8-60)**

### Research Problem

NCHRP 8-60 study shows that approximately four out of five agencies stated that they apply contingency in at least one phase of the project development process; however most of the processes used to determine the contingency lack formal definition. Research study NCHRP 8-60 shows that of 48 SHAs that responded to a survey only 8 (17%) (Figure 2) indicated that they have a formal published definition of contingency (Molenaar et al. 2008).



**Figure 2: SHAs Published Definition of Contingency (Molenaar et al. 2008)**

The issue of setting appropriate contingency is one that often poses difficulties for most State Highway Agencies. It is clear that the estimation of contingency cannot be exact because one cannot accurately predict the future. Nevertheless, the use of some structured or formalized technique for setting contingency would introduce some consistent rationale to the contingency planning process, reduce the margin of error in results, create consistency in the estimation process and aid the communication of the cost estimates to transportation stakeholders.

According to Ford (2002) contingency management requires an understanding of how managers make budget contingency decisions and the impact of those decisions on performance. However, differences between the enormous complexity of projects and the limited capacity of humans to manage complexity (Sterman 1994; Simon 1995) create a problem of how to incorporate project complexity into contingency management practice (Ford 2002).

Since every project is unique it is logical to expect that the required contingency for each one would vary based on factors such as the project size, complexity, and the level of definition at each phase of project development when the contingency is assigned. Therefore, the use of sliding contingency scales defined by and related to different project types may account for those factors that impact the project costs and contingency

through the life cycle of a project. A sliding scale is a contingency scale in which one value of contingency varies because of the influence of some other factor. For the purposes of this study the sliding contingency scale is one where the values of construction contingency vary from one phase of project development to the next based on project complexity and level of project definition. This method is similar to the Ohio design completion contingency guidelines for cost estimating of major projects (Figure 1).

### **Research Objectives**

This research addressed in part the difficulty associated with accurately estimating contingency on highway projects in the US transportation Industry. The main objective of this study is to:

develop a set of sliding scale contingencies which may be used as a guide to estimating the amount of construction contingency to include when estimating the cost of highway projects given factors such as project complexity and level of project definition.

The research attempts to address the main objective by answering the following questions:

1. While estimating the cost of capital projects in the US Highway Industry, what are some of the major factors that affect the amount of contingency provided in the cost estimate at different stages of project development?
2. How are contingency ranges affected by project type?
3. When contingency ranges are applied across the phases of project development, would the decrease in the contingency ranges tend to be linear, exponential or some other form?
4. Following from question 3, how do contingency ranges change over the life cycle of a project and what are some of the major elements that are typically included in the contingency on a project?

## 5. What is the relationship between uncertainty, risks and contingency?

Each question is associated with a research task. The corresponding tasks are listed next:

- Task 1: Review of current practice to determine methods used by US State Highway Agencies to set contingency on capital projects and some of the major factors that affect the accuracy of cost estimates.
- Task 2: Sample of expert opinions to determine the way contingency is addressed for different project types given some examples of characteristics of different project types based on complexity using attributes related to the roadway, traffic control approaches, structures, right of way, utilities, environmental requirements, stakeholder involvement and project location.
- Task 3: Review the state of practice, past studies on contingency and its applications and contingency allocation guidelines.
- Task 4: Verify the shape and range of narrowing contingency bands across the phases of project development for different project types using the input from the industry professionals and insight as to what elements are included in the contingencies.
- Task 5: A review of tasks 1 to 4 to understand the relationship between risk, uncertainty and contingency.

### **Organization of the Study**

In the chapters following the review of past literature on contingency applications, the research methodologies, the data collection method, the results and applications of the sliding scale contingencies are discussed and presented. Chapter II is a review of past research on contingency definitions, use of contingency and methods of estimating contingency. It will also show how the application of contingency may impact project cost growth. Chapter III describes the methods considered for data collection in this study. It goes further to identify an appropriate data collection method for use in this study and reviews past literature on its definitions, use, applications, benefits and

limitations. Chapter IV explains the considerations behind the data collection protocol developed and in addition describes the data collection process. Chapter V provides an analysis and a discussion of the study results. Chapter VI provides stepwise recommendations for the application of the sliding scale contingencies and describes its potential benefits if consistently applied. Chapter VII presents a summary of results and study conclusions.

## **CHAPTER II**

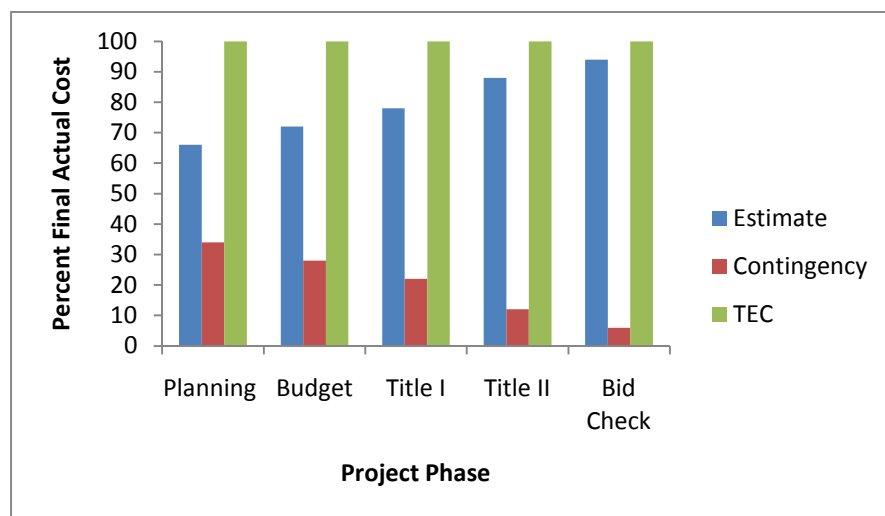
### **LITERATURE REVIEW**

Merrow and Schroeder (1991) highlighted the important link between predicting cost growth (i.e., difference between budget estimate and final actual cost) and project cost contingency by stating that cost growth can be viewed as inadequate contingency within cost estimates (Baccarini 2005). Reasonably accurate forecasts of final costs of construction projects are needed for justification of projects on economic grounds and for efficient capital planning and financing (Baccarini 2005). According to Gunhan and Arditi (2007) some of the factors that make it difficult to accurately forecast an exact budget include project complexity, the inherent uncertainty in the performance of the parties involved in the construction project, development funding issues, and the control of design and construction management costs and schedules. Contingency funds are included in budgets to provide managers flexibility to address uncertainties that threaten project objectives (Diekmann et al. 1988).

Researchers have offered many different definitions for contingency. Touran (2003) defined contingency in a construction project from the owner's point of view to be the budget that is set aside to cope with uncertainties during construction. Touran (2003) added that in general the owner anticipates that the contingency would not be needed during a project. Gunhan and Arditi (2007) defined contingency as the source of funding for unexpected events and described three classifications: designer contingency, contractor contingency and owner contingency. Designer contingency is included in the preliminary budget by the estimator for potential cost increases during the pre-construction phase of project development. Contractor contingency is included in the construction budget to cover unforeseen conditions that may occur during the construction phase. Owner contingency on the other hand is included in the owner's project budget as an additional hedge against project uncertainties which can lead to cost growth, and owner contingency is controlled by the owner. A more recent study,

NCHRP 8-60, defined contingency as an estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate. The base estimate is defined as the most likely project estimate, exclusive of project contingency, for known costs for all known construction work. Furthermore, contingency is expected to be expended during the project development and construction process (Molenaar et al. 2008).

Parsons Jr. (1999) graphically shows in Figure 3 the relationship between the total estimated cost (TEC), estimated cost and contingency, also stating that contingency is included to improve the accuracy of cost estimates by compensating for inherent inaccuracies. TEC is the ‘estimated cost’ plus ‘contingency allowance’. In the earlier phases of a project where the uncertainty is large, higher percentages of the estimated cost are included as contingency; as the project definition increases in the later phases of project development, the contingency decreases while the estimated cost increases. “Ideally, the TEC will remain constant throughout a project. As the definition of the project develops, the base estimate increases and the contingency allowance decreases” (Parsons Jr. 1999).



**Figure 3: Ideal Cost Profile – Construction Projects (Parsons Jr. 1999)**

Typically, as depicted in Figure 3, contingency is higher in the planning phase than in other phases of project development due to the low level of scope definition and inherent uncertainty. Cost uncertainty needs to be managed as a project develops throughout a project lifecycle. Molenaar et al. (2008) identified that the range of cost uncertainty should reduce as a project moves towards completion as a result of better cost variable definition. However if project problems or uncertainties included in the early cost estimates do materialize a higher cost range can be expected.

Risk management was identified as a process that can be effective in controlling or lowering the range of expected costs. Molenaar et al. (2008) stated that at any point in the project development process a cost estimate should account for three types of information:

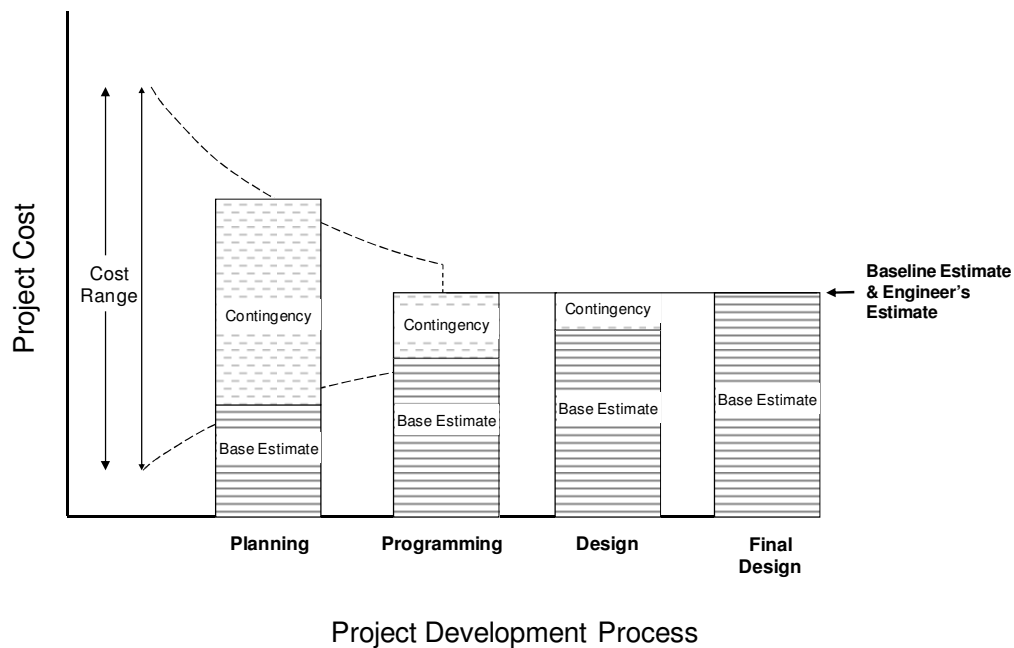
1. Known and quantifiable costs (known/knowns) which include what is defined in the scope or drawings and form a portion of the base estimate,
2. Known but not quantified costs (known/unknowns) which include costs that are known to be in the project scope but for which there are no definable quantities yet at the time of estimate preparation.
3. Unrecognized costs (unknown/unknowns) which include unforeseeable costs or costs that do not occur frequently and have the potential to make the estimate unnecessarily high.

The NCHRP 8-60 study identifies unrecognized costs and known but not quantified costs as costs that need to be accounted for in project contingency and suggests that risk management tools may be used to calculate appropriate contingencies. As shown in the ideal cost profile (Figure 3), cost estimates should comprise a base estimate and a contingency which is expected to decrease as more project information becomes available. Molenaar et al. (2008) depicted the resolution of contingency from the

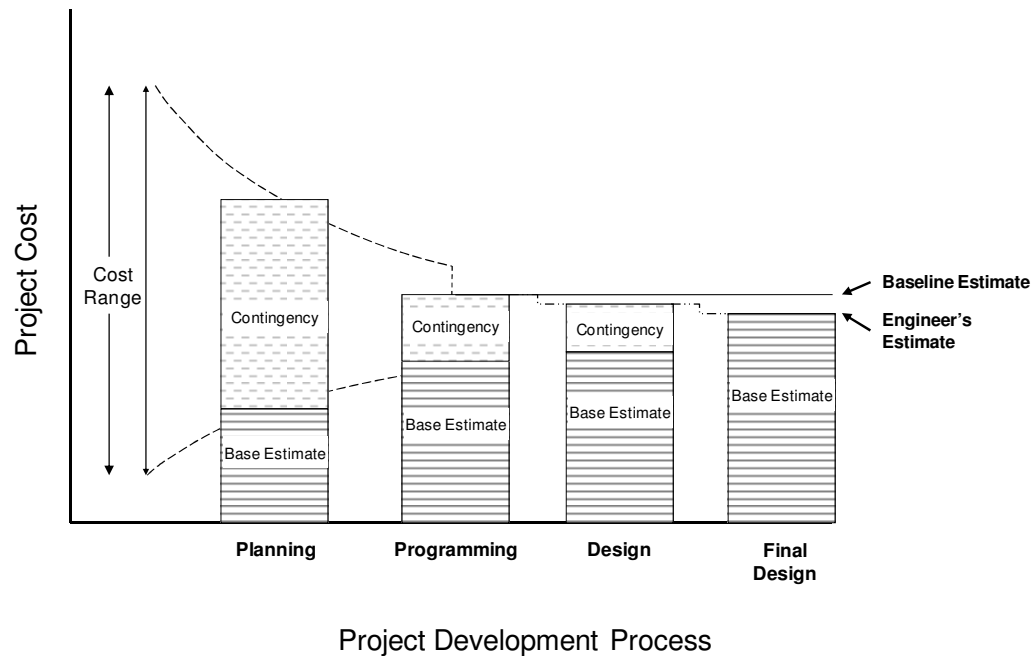


planning phase of project development to the final design phase of project development (Figures 4 and 5).

Figures 4 and 5 show the use of range estimating in planning with a wide cost range that transitions to a more deterministic estimate in programming. Programming estimates are typically used to set project baselines which can be used for cost control throughout the project lifecycle. As contingency is resolved across the phases of project development the remaining contingency should shrink as the base estimate increases as a result of better scope definition. In the final design phase the final engineer's estimate may equal the baseline estimate (Figure 4) or may be lower than the baseline estimate as shown in Figure 5 if a risk assessment was performed and risks were effectively mitigated or did not occur.



**Figure 4: Refinement of a Cost Estimate with Final Engineers Estimate Equal to the Baseline Cost Estimate (Molenaar et al. 2008)**



**Figure 5: Refinement of a Cost Estimate with Final Engineers Estimate Less than the Baseline Cost Estimate (Molenaar et al. 2008)**

Baccarini (2006) in his review of the concept of contingency highlighted several methods for estimating project cost contingency (Table 1) with examples of authors who made reference to those methods. After stressing the importance of early and accurate estimation of contingency, the author further stated that ‘the traditional percentage’ is the most commonly used estimating method in practice, followed by the recent prominence of Monte Carlo simulation, regression analysis and artificial neural networks. According to Thompson and Perry (1992) the traditional percentage method of estimating contingency is arbitrary and difficult to justify or defend.

**Table 1: Contingency – Estimating Methods (Baccarini 2006)**

<b>Contingency Estimating Methods</b>	<b>References (Examples)</b>
Traditional Percentage	Ahmad 1992; Moselhi 1997
Method of Moments	Diekmann 1983; Moselhi 1997; Yeo 1990
Monte Carlo	Lorance and Wendling 1999; Clark 2001
Factor Rating	Hackney 1985; Oberlander and Trost 2001
Individual risks – expected value	Mak, Wong and Picken 1998; 2000
Range Estimating	Curran 1989
Regression Analysis	Merrow and Yarossi 1990; Aibinu and Jagboro 2002
Artificial Neural Networks	Chen and Hartman 2000; Williams 2003
Fuzzy Sets	Paek, Lee and Ock 1993
Influence Diagrams	Diekmann and Featherman 1998
Theory of Constraints	Leach 2003
Analytical Hierarchy Process	Dey, Tabucanon and Ogunlana 1994

Donnell (2005) identified ‘inconsistent application of contingencies’ as a major factor causing cost escalation of projects stating that it causes confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts. Furthermore, Donnell (2005) stated that contingency funds are typically meant to cover a variety of possible events and problems that are not specifically identified or to account for a lack of project definition during the preparation of early planning estimates. Contingency is often misinterpreted to mean “estimating allowance”; however, an estimating allowance is defined by Molenaar et al. (2008) as an amount which is included in the base estimate for items that are known but the details of which have not yet been determined which are considered to be part of defined project scope.

Uncertainty in project cost estimates is a major source of concern more so in planning than in the later phases of project development. Identification and assessment of risk events is a way to measure the amount of uncertainty in a cost estimate. Molenaar et al (2008) suggests that risk-based cost estimates support identification of critical cost containment issues which inform the design team about risks throughout the phases of project development. Unidentified risk events contribute substantially to project

uncertainty. NCHRP 8-60 study recommends the use of risk management techniques at different phases of project development to identify and assess risks and determine associated contingencies to include in project cost estimates. The study categorized risk related tools by levels of project complexity and phase of project development.

Gunhan and Arditi (2007) proposed a four step method for budgeting owner contingency and tested it in a case study. The first step is systematically analyzing historical project data and organizing line items into standardized common categories. The second step involves identifying line items that typically make use of contingency funds by scrutinizing budgeted and actual cost information for similar line items from past projects identified in step 1. The third step is taking the necessary measures at the preconstruction stage to minimize occurrence of events identified in step 2. The fourth and final step is the process of estimating the size of contingency funds required based on the information obtained in the previous steps 1, 2 and 3. The findings of this and four other studies will be discussed briefly in the next subsection.

### **Applications of Contingency**

In this section five studies will be reviewed that highlight the use of contingencies in project estimates.

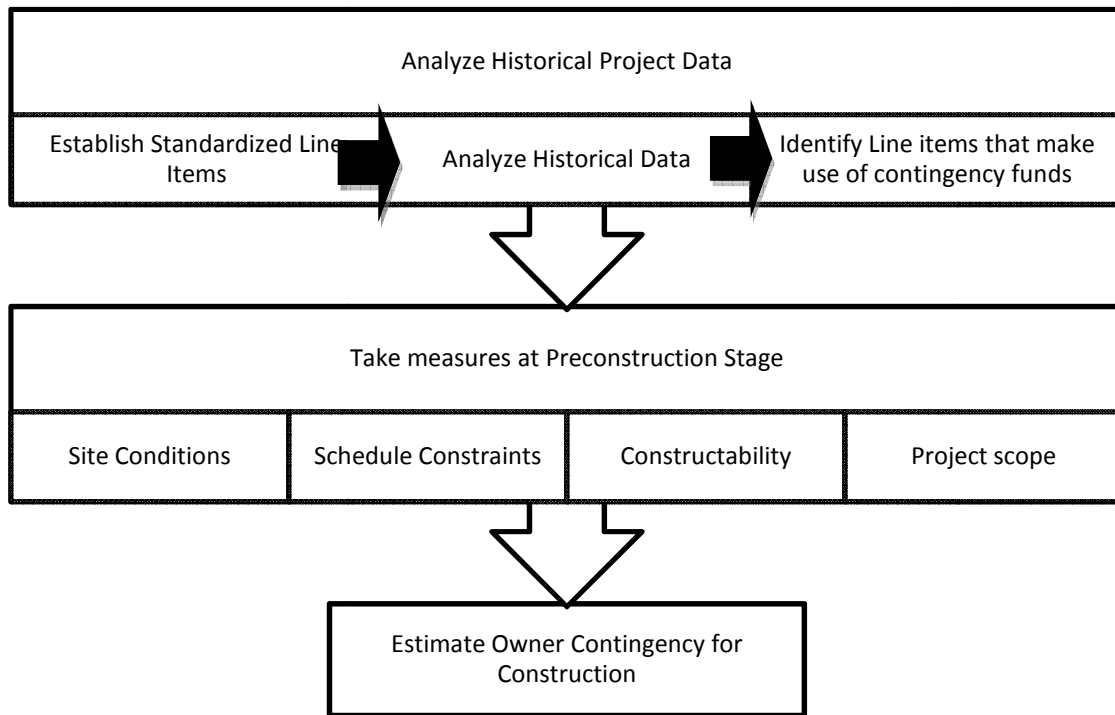
#### Budgeting Owner's Construction Contingency – Gunhan and Arditi (2007)

The authors proposed a four step method for estimating owner contingency as described in the preceding section. This method was tested on a case study where cost data were extracted from nine parking lot projects built at airports belonging to a major city in the United States. The data included line item costs and changes for projects with costs ranging from \$237,000 to \$9.45 million. The number of line items for each project varied between 15 and 150 but was consolidated into 20 standard line items; examples of the line items are traffic control, utilities relocation, drainage work, excavation, asphalt

paving, landscaping, parking control devices and geotechnical work. The owner added 10 percent contingency on all the projects to cover changes and contract variations.

The analysis began with a comparison between actual costs of change orders for each line item with their existing budgets. By expressing the average actual contingency funds used as a percentage of the contract value, the authors were able to determine the line items with the highest cost overruns. The average actual contingency used across the nine projects was 3.86 percent, however the maximum and minimum used on an individual project basis were 21.37 percent and -7.59 percent respectively. -7.59 percent contingency indicates that the allotted contingency was not used and the project was completed under budget. Four of the nine projects examined did not use any contingency and were completed under budget. Generally it was found that the majority of the line item contingencies had been underestimated except for a few; examples include parking control devices which were overestimated by as much as 31.8 percent on average and contaminated soil disposal overestimated by as much as 43.9 percent on average.

The authors concluded that the owner allotting 10 percent contingency to each project was excessive and added that the use of a systematic approach can help owners assign contingency commensurate with the project and contract conditions. The proposed approach is shown in Figure 6.



**Figure 6: Budgeting Owner Contingency (Gunhan and Arditi 2007)**

Understanding Project Cost Contingency – A Survey by Baccarini D. (2005)

Baccarini (2005) conducted a survey of seventy-eight professionals (mainly Project Managers) primarily in the Construction/Engineering industry and the Information Technology industry; these represented eighty-one percent of the research sample population. Representatives were present both from the public and private sectors.

Seventy-three percent of the respondents described contingency as a provision, reserve of money or allowance. Other definitions include: a risk; unexpected or unforeseen circumstance; cost overrun; known unknowns, unknown unknowns; underestimation; and undefined scope. Fifty-five percent stated that contingency should not be used to fund scope change, while others mentioned exclusions such as estimation errors, risks, inflation, and delay costs.

Contingencies are often calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data (Mak et al. 1998). Seventy-seven percent of the respondents indicated that they use this approach, twenty-one percent said they do not, and 2 percent said they do not know. The use of this percentage addition method is a single figure prediction, which indicates the potential for downside risk and does not indicate any potential for cost saving opportunities and may therefore mask poor project management (Mak et al. 1998). When asked whether any review is performed to check the accuracy of project cost contingency, only thirty-six percent of the respondents said yes, sixty-two percent said no and 2 percent did not know.

Since organizations need to review and continuously improve as part of the quality management processes, post-project reviews are required to check that calculated contingencies match as closely as possible to the actual costs incurred in a project for which contingency is meant to cater. Without a review it is difficult to capture organizational knowledge that can lead to improved process (Baccarini 2005). Furthermore forty-six percent of the respondents indicated that their organizations do not have formal policies for project cost contingency, forty-nine percent said yes they have and 2 percent said they did not know. Judging by the forty-six percent that do not have policies, this suggests that there is significant room for improvement in the organization's whole approach to project cost contingency (Baccarini 2005). The author, Baccarini (2005), highlighted a point also made by Hamburger (1994) that one way to ensure a consistency is to establish guidelines to define and control the scope, estimation and management of contingencies.

Baccarini (2005) concluded by stating that there seems to be absence of the awareness that project cost contingency is a risk management concept, perhaps explaining the deterministic approach of adding an across-the-board percentage to the base estimate when estimating contingency. In addition the lack of sophistication in the estimation of

project cost contingency by practitioners is reinforced by poor management practices in terms of reviewing the accuracy of contingency and the limited existence of policy and good management practices.

Waste Management Project Contingency Analysis – Parsons Jr. (1999)

This study provided the office of Waste Management (WM) with recommended contingency calculation procedures for typical WM projects in treatment, storage, and disposal of low level, mixed low level, hazardous, transuranic, and high level waste (Parsons Jr. 1999). Different definitions of contingency, types of cost estimates and their applications were reviewed to determine what the recommended practice should be for use by the WM office.

In this study contingency was defined by the Association for the Advancement of Cost Engineering (AACEI 1998) as “an amount added to an estimate to allow for additional costs that experience shows will likely be required. Contingency amounts may be determined either through statistical analysis of past project costs, or by applying experience gained on similar projects. It was noted that contingency usually does not include changes in scope or schedule or unforeseeable major events such as strikes or earthquakes” (AACEI 1998). Parsons Jr. (1999) identified two types of contingencies that are used to compensate for the different types of uncertainties typically encountered in engineering projects – project contingency and process contingency. Project contingency is based on the degree of project definition available at the time of estimate preparation. It covers expected omissions and unforeseen costs caused by lack of complete engineering. Process contingency on the other hand is based on the degree of uncertainty caused by use of new technology. It is an effort to quantify the uncertainty in performance because of limited technical data (Parsons Jr. 1999).

The recommended values of contingency were calculated using a combination of process and project contingencies. The calculated values change according to the technology



status and the phase of project development. Immediately following are the AACE-recommended process contingency allowances for each technology situation (Table 2) and the recommended project contingency allowances by project phase (Table 3) (Parsons Jr. 1999).

**Table 2: Process Contingency Allowance per WBS Item (Parsons Jr. 1999)**  
(Expressed as a percentage of estimated cost)

STATE OF DEVELOPMENT	AACE RECOMMENDATION
New Design beyond State of the Art (SOTA)	40% +
New Design Hardware through Conceptual Design Report (CDR)	30 - 70%
New Design Hardware through Preliminary Design Report (PDR)	20 – 35%
Modifications Required to Existing Hardware	5 – 20%
No Modifications Required	0 – 10%

**Table 3: Recommended Project Contingency Allowances (Parsons Jr. 1999)**  
(Expressed as a percentage of estimated cost)

PROJECT STAGE	PROJECT CONTINGENCY	DESIGN COMPLETE
Planning	50%	0 -2%
Conceptual	40%	1 – 5%
Title I	30%	5 – 20%
Title II	15%	20 – 50%
Construction	5%	50 – 100%

A total estimated cost (TEC) was derived for each element in the Work Breakdown Structure (WBS) combining process and project contingency. Total estimated cost is calculated using:

$$\text{TEC} = \text{Estimated Cost} + \text{Total Contingency Allowance} \quad (1)$$

Where the total contingency allowance is expressed as:

$$\text{Total Contingency Allowance} = \text{Project Contingency} + \text{Process Contingency} \quad (2)$$

Total contingency allowances are summarized versus project phase at different stages of technical readiness. Process stages range from new designs beyond the current state of the art to designs with existing hardware which may be used without modification (Parsons Jr. 1999). This is illustrated in Tables 4 and 5:

**Table 4: Recommended Contingency Allowances for a New Design that Requires State of the Art (SOTA) Technology (Expressed as a Percentage of Estimated Cost) (Parsons Jr. 1999)**

Project Phase	Contingency			Design Complete
	Project	Process	Total	
Planning	50%	40%+	90%+	0 – 2%
Title I	30%	40%+	70%+	5 – 20%
Title II	15%	40%+	55%+	20 – 50%
Construction	5%	40%+	45%+	50 – 100%

**Table 5: Recommended Contingency Allowances for a New Design with Conceptual Design Report (CDR) (Expressed as a Percentage of Estimated Cost) (Parsons Jr. 1999)**

Project Phase	Contingency			Design Complete
	Project	Process	Total	
Planning	40%	30 – 70%+	70 – 110%+	0 – 2%
Title I	30%	30 – 70%+	60 – 100%+	5 – 20%
Title II	15%	30 – 70%+	45 – 85%+	20 – 50%
Construction	5%	30 – 70%+	35 – 75%+	50 – 100%

Similar calculations were done for new design with Preliminary Design Report (PDR) and designs with modifications to existing software for illustrative purposes. The TEC for the entire project is the sum of the TECs for all the WBS elements.

For budgeting contingency on large construction projects, Parsons Jr. (1999) recommended that contingency be calculated as shown:

$$\begin{aligned} \text{TEC} &= \text{Cost Incurred to date} \\ &+ \text{Estimated Remaining Cost} + \text{Scaled Contingency Allowance} \end{aligned} \quad (3)$$

$$\begin{aligned} \text{Scaled Contingency Allowance} &= \text{Original Contingency Allowance} \\ &\times (\% \text{ work remaining}/100) \end{aligned} \quad (4)$$

The following example was given by Parsons: Consider a construction project in which \$100 million was the estimated cost for a major WBS element with a contingency

allowance of \$5 million, yielding a TEC of \$105 million. If the construction phase on the element is 50% complete:

Current working TEC (to complete the element) = costs incurred to date + estimated cost remaining +  $(\$5\text{M} \times 50/100)$ , where  $(\$5\text{M} \times 50/100)$  is the scaled contingency allowance.

By using this approach Parsons Jr. (1999) suggests that for current working estimates of cost-to-complete during the construction phase the contingency reserve budgeted at the start of construction be tapered off linearly as the project progresses based on the construction work accomplished.

Using Risk Analysis to determine Construction Project Contingencies – Mak and Picken (2000)

This paper presents the results of a study of the effect of Estimating using Risk Analysis (ERA) carried out to compare the variability and consistency of the contingency estimates between non-ERA and ERA projects.

In construction and development projects, the basic notion of risk analysis is that it is useful to at least make an attempt to identify the risky items and attach some financial value to them. These amounts can then be added to a project budget as items of possible expenditure with the intention that this budget then becomes a more realistic representation of the client's likely outlay. Mak and Picken (2000) stated that in an attempt to deal with the determination of contingencies in a more analytical way the Hong Kong Government implemented a technique called Estimating using Risk Analysis (ERA) in 1993. The process is used to estimate contingency of a project by identifying and costing risk events associated with that project.

In this ERA process risks are categorized as ‘fixed’ or ‘variable’ and an average risk allowance or maximum risk allowance is calculated for each risk item using the algorithms in Table 6. The authors defined fixed risk events as those that either happen in total or not at all adding that if the event happens, the maximum cost will be incurred; but if not, then no cost will be incurred, that is, a risk is associated with a probability of occurrence but the consequence (monetary) is fixed if it occurs. This cost would be the maximum risk allowance while the average risk allowance is the probability of the event occurring multiplied by the maximum risk allowance (Mak and Picken 2000). The authors gave the example of a client who at the early stages of a project is uncertain as to whether or not the construction of an additional access road would be required. If the road is required the full cost of developing the road will be incurred and is equivalent to the maximum risk allowance. However, if the road is not required no costs would be incurred. This characteristic makes it a fixed risk item; certainly, the scope of the road can be known if required and used to determine the maximum risk allowance.

**Table 6: Relationship between Risk Allowance and Risk Category in ERA  
(Mak and Picken 2000)**

Type of Risk (1)	Average risk allowance (2)	Maximum risk allowance (3)
Fixed Risk	Probability x maximum cost	Maximum cost
Variable Risk	Estimated Separately	Estimated separately
Assumption	50% Chance of being exceeded	10% chance of being exceeded

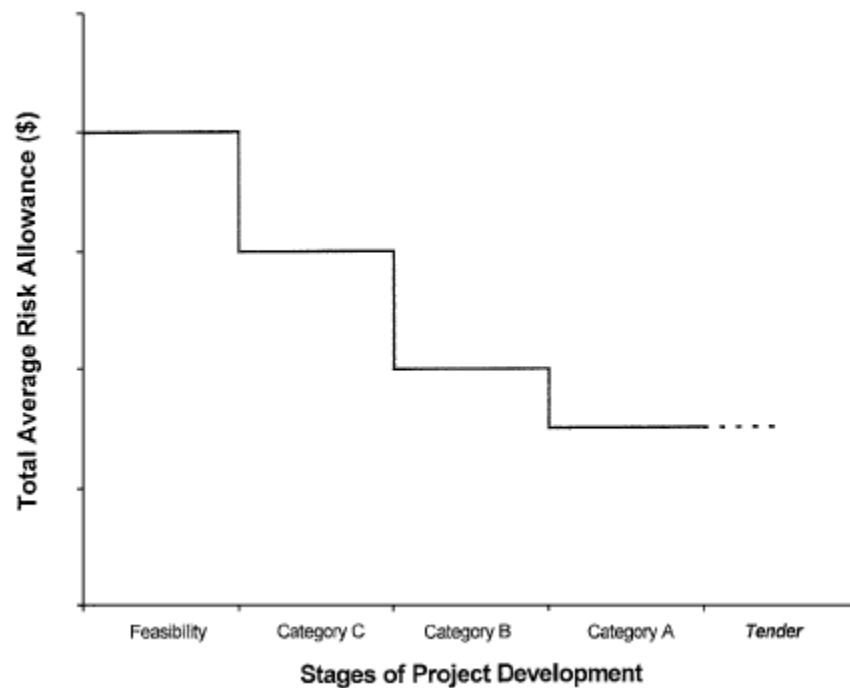
On the other hand “Variable risk events are those events that will occur, but the extent to which they will occur is uncertain. The cost incurred will therefore be uncertain and variable” (Mak and Picken 2000). The example given is the depth of piles to be driven. The maximum risk allowance is estimated by the project team members based on past experience or records. The maximum risk allowance is the cost of the most expensive

type of piling required at the maximum length. The following assumption needs to be made when using the Hong Kong Government's ERA method: that there is only a 10% chance that the actual cost incurred will exceed this allowance and the average risk allowance is estimated with an assumption that there is a 50% chance of being exceeded. According to Mak and Picken (2000) the rationale behind the use of 50% is that it is unusual for all identified risks (i.e., the worst case) to occur. A typical ERA worksheet (Figure 7) is shown. The summation of the average risk allowances for all the risk events will become the contingency of the project concerned.

The ERA is usually carried out several times during the pretender stage for any one project. As the project develops and more and more uncertainties become resolved they are deleted from the risk events or included in the base estimate as a certainty. The remaining uncertainties will form the final contingency allowance; the total average risk allowance evolves (Figure 8) at successive ERA exercises as more becomes known about the uncertain items identified (Mak and Picken 2000).

ERA Calculation						
Project: Construction of the Central Library Client: Urban Council				Date: 2 March 1995 ERA Run: 1		
(1) Risk	(2) Type	(3) Probability (Fixed Risks Only)	(4) Average Risk Allowance \$	(5) Max. Risk Allowance \$	(6) Spread (5) - (4) \$ M	(7) Spread square d \$ M
Design Development	V		8,400,000	12,600,000	4.2	17.64
Additional Space	F	.70	11,760,000	16,800,000	5.04	25.4016
Site Conditions	V		525,000	1,000,000	.475	0.2256
Market Conditions	V		4,000,000	8,500,000	4.5	20.25
A/C Cooling Source	V		250,000	1,250,000	1	1
Access Road	F	.50	250,000	500,000	.25	0.0625
Additional Client Requirements	V		1,680,000	4,200,000	2.52	6.3504
Contract Variations	V		8,400,000	12,600,000	4.2	17.64
Project Co-ordination	V		500,000	1,500,000	1	1
Contract Period	F	.60	1,000,000	1,750,000	.75	0.5625
			36,765,000			90.1326
					Sq Root	9.494
Maximum Likely Addition = \$9,494,000						
Base Estimate = \$168,000,000						
Average Risk Estimate = Base Estimate + Total Average Risk Allowance						
= \$204,765,000 (21.88% on base)						
Maximum Likely Estimate = Base Estimate + Average Risk Allowance + Maximum Likely Addition						
= \$214,259,000 (27.54% on base)						
<i>Note: The Maximum Likely Addition is the figure (the additional amount) which would flow from a situation where every identified risk identified by the project group occurs in total with maximum financial consequences. This is seen as a catastrophic set of circumstances. The mathematical expression of the combined effect of the maximum risk allowances is that they do not add together by simple addition. This situation is dealt with by the Central Limit Theorem - that is the various maximum risk allowances for each risk add together by the sum of their squares.</i>						

**Figure 7: Example of ERA Worksheet at Sketch Design Stage  
(Mak and Picken 2000)**



**Figure 8: Total Risk Allowance versus Stages of Project Development  
(Mak and Picken 2000)**

The paper compares the contingency estimates and final account variations of public works projects by analyzing data sets of pre-1993 (non-ERA) and post-1993 (ERA) projects. The Hong Kong Government in 1997 provided a summary of completed projects that detailed the contract sum, original contingency, amount of additions, amount of omissions, final account amount, and the start date of 332 building projects, 45 of which used the ERA method to determine the contingencies and 287 with contingencies determined by the traditional method. Contingency allowances were compared against variations since all the projects were carried out using the government's standard form of contract. An analysis of the F-statistic and the t-statistic were carried out. It was concluded that the variability of contingency allowance for the non-ERA projects was much higher and that the contingency allowance for ERA projects was more consistent. The implication of the results is that 115% more funds were set aside for uncertainties in ERA projects compared to an average of 215% more



for non-ERA projects. The exaggeration of contingencies 115% for ERA and 215% for the non-ERA projects has led to a severe misallocation of resources for the projects, though much more severe for non-ERA projects. This misallocation of resources often means that some projects under consideration in a given phase of a public works program have to be foregone or deferred due to insufficient funds (Mak and Picken 2000). On the average, it was considered that the contingency allowance for ERA projects was still very high indicating a need to further refine the ERA techniques. Possible solutions may include: (1) the provision of historical project records for making knowledgeable estimates; (2) a review of the policy of capital budgeting; and (3) a study of the effects of positive and negative sanctions on estimators (Mak and Picken 2000).

In addition, a survey was conducted in which estimators were required to rank on a scale of 1 to 5 the importance of three factors for their using ERA. In particular three areas were identified, namely, ERA being a policy requirement, ERA helping to identify accountability, and ERA's potential for accuracy in determining contingency allowances. The findings from the survey are shown (Table 7). Most of the respondents who were government officials considered policy to be the most important factor for using the ERA, and accuracy the least important (Mak and Picken 2000).

**Table 7: Summary of Feedback from Survey (Mak and Picken 2000)**

Rank (1)	Policy requirement (2)	Accountability (3)	Accuracy (4)
1 (most important)	15	2	1
2	2	9	7
3	3	5	6
4	1	3	4
5 (least important)	0	2	3
Number of respondents	21	21	21
Severity index	86.90	57.14	48.81

“From the feedback of estimators who were using ERA, it was found that they used ERA because they were required to do so and they viewed ERA as a mechanism of accountability more than a way of improving the accuracy of estimating. Nonetheless, they also expressed the insufficiency of historical data for them to make better estimates of uncertainties” (Mak and Picken 2000).

NCHRP 8-60 “Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs” – Molenaar et al. (2008)

The main objective of this project was to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs.

In the earlier phases of the project, the project team conducted a survey of state highway agencies to review and document current industry practice with respect to risk assessment and contingency allocation as it pertains to cost estimating and control. In this study contingency is defined as the estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate. A total of 48 of 52 state agencies responded in the survey and generally agreed that contingency is necessary in their cost estimates, but there is inconsistency concerning what is included in a contingency amount and how it should be calculated. It was found that only 8 of the 48 responding agencies have a formal published definition of contingency. Without a formal published definition for contingency, agencies will have a difficult time consistently calculating appropriate contingencies and explaining what contingency covers (Molenaar et al 2008).

The agencies set contingency using three primary methods: 1) a standard predetermined contingency; 2) use of a unique project contingency set by project estimators; and 3) use of formal risk analysis and associated contingency. Sixteen of the 48 state agencies were found to be using some form of standard predetermined contingency on their projects;

some of the others set unique project contingencies; while the remaining ones either use some form of risk analysis or a combination of risk analysis and unique project contingency.

From the survey responses some of the agencies including California State Department of Transportation (Caltrans), Washington State Department of Transportation (WSDOT), Maryland, Florida, Ohio and Nevada Department of Transportation all use some form of contingency scales within their project development phases. For example, Caltrans uses contingency factors that vary depending on the type of estimate and reduce with increased project definition across the phases of project development (Table 8).

**Table 8: Caltrans Contingency Scale (Molenaar et al. 2008)**

<b>Estimate Type</b>	<b>Contingency</b>
Planning Estimates	25%
General Plan Estimates	20%
Marginal Estimate - Final PS&E	5%

Florida DOT uses both project contingencies and program contingencies across the board for all projects. The districts set contingency amounts based on available funds. The program contingency covers project changes, additional projects added to the program, cost increases and supplemental agreements (change orders) while the project contingency covers scope additions/refinements and bid unit price escalations (Molenaar et al. 2008). Maryland, Nevada and Washington State DOTs use contingency scales similar to the Caltrans scale for contingency at three levels. Table 9 shows the Florida DOT contingency factors.

**Table 9: Florida DOT Contingency Factors (Molenaar et al. 2008)**

Project Phase	Project Unknown Factor
Initial Cost Estimate	25%
Design Scope of Work	20%
Design Phase I (30%)	15%
Design Phase II (60%)	10%
Design Phase III (90%)	5%
Design Phase IV (100%)	0%

Estimates can be communicated in two different ways: 1) as a range; or 2) as a point estimate. Ranges give the estimate in a form which may be shown graphically with a probability curve; using ranges it is expected that the actual cost would be somewhere between the two extremes of the range. Some of the agencies communicate their estimates as ranges. Table 10 provides a summary of the agencies use of ranges in communicating cost estimates and results of the survey showed that range estimates are a viable method for communicating project cost estimates (Molenaar et al. 2008).

**Table 10: Use of Ranges to Communicate Estimates (Molenaar et al. 2008)**

PROJECT DEVELOPMENT PHASES	NEVER USE RANGES	SOMETIMES USE RANGES	ALWAYS USE RANGES
Planning	36%	55%	9%
Programming and Preliminary Design	53%	38%	9%
Final Design	70%	19%	11%

## Summary

Chapter II reviewed different definitions of contingency as used by authors on past research. Several methods were also identified for estimating contingency on projects and communicating estimates to stakeholders. NCHRP 8-60 provides a comprehensive review of SHA methodologies for estimating contingency on highway projects.

Association for the Advancement of Cost Engineering International (AACEI) recommended practice on cost estimating provides some guidelines for the estimation of

project contingency by practitioners. They are general principles which may be found reliable for use on projects where applicable or for practitioners to adapt to suit their particular projects. Hollmann (2008) described four (4) methods for estimating contingency:

- Expert Judgment; the method relies on the experience of qualified professionals with competencies in risk management and analysis.
- Predetermined Guidelines which may be a simple percentage of the base cost or duration. Should be used with varying degrees of judgment to suit project situation.
- Simulation Analysis, which is a method which combines expert judgment with an analytical model to provide probabilistic output; the two most common applications of simulation analysis are range estimating and expected value methods using Monte Carlo or similar simulation programs.
- Parametric Modeling which may employ the use of regression analysis of historical project data.

While emphasizing the need for contingency it is also important to note that budgeting contingency in excess of project requirements could also tie up funds which may otherwise have been allocated to other projects. According to Gunhan and Arditi (2007) freeing up contingency funds allows owners to undertake a larger number of projects.

### **CHAPTER III**

#### **RESEARCH METHODOLOGY**

The use of experimental research methods was considered in this study but found to be unsuitable for this study. Experimental research relies on the manipulation of an independent variable to determine its effect on a dependent variable and understand the causal processes involved. It can be used where there is a predictable cause and effect relationship with the effect always remaining the same. In this study, any of several factors such as project type, estimation method and time of estimate preparation could typically affect the cost or the amount of contingency allocated to a construction project. It may be possible to determine that a certain factor would have an effect on the amount of contingency. However, some of the factors are interrelated and every project is unique, it may therefore be difficult or impossible to predict an exact effect on the amount of contingency based on any single factor. To be considered an experimental study it must be possible to determine a causal relationship between the variables and a substantial amount of data is also needed. Furthermore, the nature of the research being fact-finding makes it difficult to formulate a specific hypothesis to prove or disprove.

Non-experimental research is used when variables of interest cannot be manipulated because they are naturally existing attributes or when random assignment of individuals to a given treatment condition would be unethical (Belli 2008). Non-experimental research techniques were found to be more applicable due to the nature of the study; it is possible to establish that some factors will have an effect on contingency but it is not possible to determine the exact effect or extent of the relationship since any one of the other factors can lead to the same or a similar effect.

Case studies, interviews and surveys are non-experimental techniques that could possibly be used in this study. Case studies may be used to provide an in depth analysis of a few projects at a time, they can be time consuming and lead to bias in the results due

to the case study selection. Survey interviews (phone or face-to-face) on the other hand when framed in good context can be very advantageous to the study. The use of open ended questions gives room for detailed explanations and immediate clarifications when necessary. Unfortunately, this method can be expensive and some interviewees may be intimidated by the interviewer and leave out vital information in their responses. The third method considered was the questionnaire survey method which is a very detailed and systematic method of data collection. While questionnaire surveys may often yield very good results, there is also a tendency for the respondent to be overwhelmed if the questionnaire is too detailed and leaves out vital information. The Delphi method was the final method considered; it is an adaptation of the questionnaire survey method and is used to obtain the judgment of a panel of experts on a complex issue or topic. It is a systematic method of data collection that aims to minimize the effects of bias due to the characteristic lack of anonymity in interviews and general surveys.

The Delphi Technique was used to accomplish the objectives of this study. It is a method that is particularly useful in situations when empirical means are not suitable; the results of such studies would rely heavily on the subjective opinions of experts. Applied to this study, the Delphi method relied on the experience of experts in different fields within the Highway Industry to determine contingency ranges for different project types and what was included in such contingencies. Past studies including some in the highway industry have shown that the method is reliable when appropriately tailored to suit a particular problem.

The Delphi technique is a qualitative, long-range forecasting technique that elicits, refines and draws upon the collective opinion and expertise of a panel of experts (Gupta and Clarke 1996). It is based on the principle that forecasts from a structured group of experts are more accurate than those from unstructured groups or individuals (Rowe and Wright 2001). A group of authors (Linstone and Turoff 2002) offered the following more general definition of the Delphi technique: “Delphi may be characterized as a

method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.” According to Hallowell and Gambatese (2009) the specific objectives of the Delphi method are fourfold: 1) to gain insight from a group of experts on a specific topic 2) to establish a degree of consensus 3) to maintain anonymity of diverse expert panel members and 4) to answer a question that cannot be addressed using standard statistical procedures.

### **Background of the Delphi Technique**

The Delphi concept may be viewed as one of the spinoffs of defense research. "Project Delphi" was the name given to an Air Force-sponsored Rand Corporation study, starting in the early 1950's, concerning the use of expert opinion (Dalkey and Helmer 1963). The objective of the original study was to "obtain the most reliable consensus of opinion of a group of experts ... by a series of intensive questionnaires interspersed with controlled opinion feedback." (Linstone and Turoff 2002). Delphi was originally developed for market research and sales forecasting purposes (Goldfisher, 1992). The method became popular only after the first article describing it was published in 1963 (Gupta and Clarke 1996). Delphi is an iterative forecasting procedure characterized by three features (Dickey and Watts 1978): anonymity; iteration with controlled feedback; and statistical response. It is conducted by rounds interspersed with group opinion and information feedback in the form of relevant statistical data (Chan et al. 2001). Delphi technique has become a fundamental tool for those in the area of technological forecasting and is used today in many technologically oriented corporations. Even in the area of "classical" management science and operations research there is a growing recognition of the need to incorporate subjective information (e.g., risk analysis) directly into evaluation models dealing with the more complex problems facing society such as environment, health and transportation. Because of this, Delphi is now finding application in these fields as well (Linstone and Turoff 2002).



The appropriateness of utilizing Delphi is determined by the particular circumstances surrounding the necessarily associated group communication process. According to Linstone and Turoff (2002) the following questions need to be addressed before the decision is made about whether or not the Delphi method is appropriate for use:

Who is it that should communicate about the problem?

What alternative mechanisms are available for that communication?

What can we expect to obtain with these alternatives?

After these questions have been addressed, typically, one or more of the following properties of the application leads to the need for employing Delphi (Linstone and Turoff 2002):

- The problem is complex and relies more on the subjective and collective judgment of experts than on the use of experimental techniques to achieve a solution
- The individuals that would make up the panel of experts for the solution of a complex problem may represent diverse backgrounds in areas of expertise relevant to the problem
- More individuals are needed than can effectively interact in a face-to-face exchange
- Frequent group meetings may not be achievable due to time and cost requirements
- The efficiency of face-to-face meetings can be increased by a supplemental group communication process
- The heterogeneity of the participants must be preserved to assure validity of the results, that is, avoidance of domination by quantity or by strength of personality (bandwagon effect)
- Anonymity and adjudication must be assured to prevent the occurrence of severe disagreements among individuals that make up the group of experts

(Ali 2005) distinguished between two approaches of the Delphi technique: Conventional and Policy. Conventional Delphi is a “decision-making tool” that has been adopted in most Delphi studies. On the other hand, policy Delphi is a “decision-facilitation tool” to generate possible opposing views for certain policy issues by participants who are not necessarily experts in the research topic of inquiry (De Loe, 1995; Linstone and Turoff, 2002). Unlike conventional Delphi, policy Delphi does not seek to build consensus among panelists, but attempts to generate alternatives or arguments for and against certain policies. Alternatives produced by Delphi policy help policy makers choose the most appropriate policies (Turoff and Hiltz, 1996).

### **Panel Selection**

The success of a Delphi study rests on the combined expertise of the participants who make up the expert panel (Powell 2003). Sometimes, Delphi participants are selected through a “nomination” process in which recognized experts are solicited but also asked to provide names of other experts (Streveler et al. 2003). For this method to be successful in achieving its objectives, it is important that expert panel members are willing and able to make a valid contribution (Linstone and Turoff 2002). The selection of experts is an intricate problem even when the category of expertise needed is well defined. A man’s expertness might be judged by his status among his peers, by his years of professional experience, by his own self-appraisal of relative competence in different areas of inquiry, by the amount of relevant information to which he has access or by some combination of objective indices and a priori judgment factor (Brown 1968). It has been suggested that experts be selected from varied backgrounds in order to guarantee a wide base of knowledge (Rowe 1994); diversity of expert panel membership leads to better performance as this may allow for the consideration of different perspectives and a wider range of alternatives (Murphy et al. 1998). In a study on the application of Delphi method in selection of procurement systems for construction projects the following criteria were devised to correctly identify eligible participants for the Delphi surveys in Hong Kong (Chan et al. 2001):

1. Practitioners to have extensive working experience in the construction industry in Hong Kong.
2. Experts to be currently, recently or directly involved in the management of construction projects in Hong Kong.
3. Experts to have a detailed knowledge of all the procurement options.

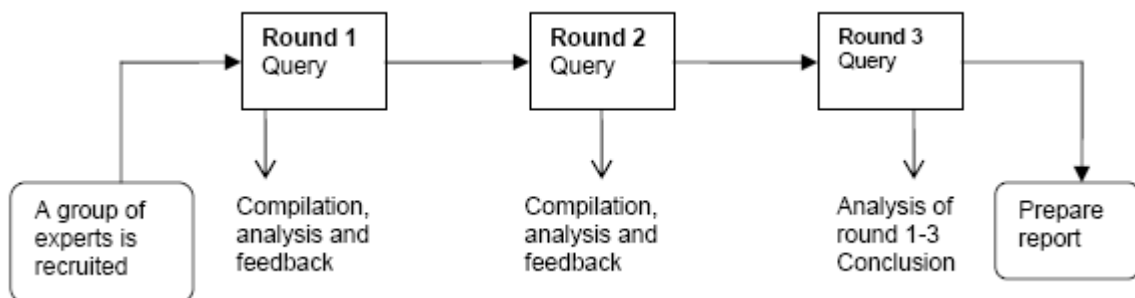
There is a large amount of variation in the size of the panel. A recommendation for panel size is 5 to 20 experts with disparate knowledge (Rowe and Wright 2001). In a Delphi study related to thermal and transport science reference was made to Clayton's rule of thumb that 15 to 30 people are an adequate panel size; 31 of 35 people agreed to be on that panel (Streveler et al. 2003). Guidance suggests that numbers of participants will vary according to the scope of the problem and the resources available (Delbecq et al. 1975). There is the belief that the more the participants the better the results. However, it was also stated that there is very little actual empirical evidence on the effect of the number of participants on the reliability or validity of consensus processes (Murphy et al. 1998).

### **The Delphi Survey**

Studies show that some applications of the Delphi process have been accomplished in three rounds and others in more rounds. Brown (1968) described the Delphi application as a four-round process in an illustrative example: "What will the world population be in the year 2000?" The iterative nature of the procedure generates new information for panelists in each round, enabling them to modify their assessments and project them beyond their own subjective opinions. It can represent the best forecast available from a consensus of experts (Corotis et al. 1981). Typically, three rounds of questionnaires are sent to a preselected expert panel, although the decision over the number of rounds is largely pragmatic (Jones et al. 1992). The Delphi Method requires a minimum of two rounds beyond which the number of rounds is disputed (Thangaratinam and Redman

2005). It was noted that “repeated rounds may lead to fatigue by respondents and increased attrition” (Walker and Selfe 1996).

The first round of the Delphi involves the use of open-ended questions to identify issues to be addressed in subsequent rounds. These sort of questions are recognized to increase the richness of the data collected (Bond and Bond 1982; Powell 2003). This forms the basis for the next round. The facilitator reviews and compiles the responses received in the first round, and prepares feedback for the panel of experts. More specific questions are then prepared based on this review and sent along with the feedback as part of the Second round. The experts may choose to review their initial opinion based on the feedback from round one. A special feature of the Delphi approach is controlled feedback to the respondents each round (Dalkey 1969). Similar procedures are followed for subsequent rounds until a consensus is reached. Consensus does not denote an objectively correct answer, but rather the attainment of a reasonable and reliable estimation of a solution (Lindqvist and Nordanger 2007). In Figure 9, consensus was achieved in three rounds.



**Figure 9: General Scheme of the Delphi Study Process  
(Lindqvist and Nordanger 2007)**

Hallowell and Gambatese (2009) pointed out that it is common to use variance as a measure of consensus, but the guidance that describes the level of variance that represents “consensus” is not available in literature, perhaps, because the data collected for nearly every study is unique.

### **Delphi Applications**

The Delphi method, over the last three decades, has gained increasing popularity and has been applied in many fields to solve complex qualitative and quantitative problems. Examples of some of the fields are medical science (Jones et al. 1992; Thangaratinam and Redman 2005), education (Liu and Lin 2009), clinical nursing (Lindeman 1975), construction (Touran 2003; Rowe 2006; Gunhan and Arditi 2007; Yeung et al. 2009), highway research (Patil 2000; Damron 2001), energy (Garde et al. 1985) and project management (Ford 2002). This section highlights a few of the Delphi applications.

#### Developing Evaluative Indicators for Educational Computer Games (Liu and Lin 2009)

In this study, the panel members included educational technology experts, educational psychology experts, game design experts, elementary school students and high school students with at least a year of experience in using educational computer games for learning and six school teachers with at least a year of experience in using educational computer games for teaching.

In the first round, based on their opinions and the results of the content analysis of 196 games, the experts listed the necessary evaluative indicators. The questionnaires for the second and third rounds were produced based on an analysis of these lists. The Delphi study was concluded in four rounds when the consistency was observed in the opinions of the panel members.

Identification of Research and Development Needs in Highway Construction Engineering and Management (Damron A.J., 2001)

The aim of this study was to identify, assess and prioritize critical Highway Construction Engineering and Management (CEM) research needs. A Delphi study was conducted with industry professionals in three (3) rounds; the first and second were used to identify and rank critical issues, while the third round was used to prioritize the top 20 issues. The study was concluded in three rounds; research problem statements were drafted using the information obtained from the surveys.

Optimal Owner Contractor Relationships based on Capital Project Competencies (Patil S.S., 2000)

This Delphi study was conducted to validate a modified Owner/Contractor Work Structure (OCWS) process initially developed by the Construction Industry Institute (CII). The OCWS is a systematic decision process designed to aid company executives in determining appropriate owner/contractor working relationships for stakeholders' competencies on a project. Two (2) rounds of surveys were performed involving experienced project managers from 32 owner companies and 2 consulting companies in North America. Participants were required to assess an overview of the modified OCWS process and express their levels of agreement using structured response protocol which was revised for round 2 based on the responses from the first round.

**Advantages and Limitations of the Delphi Technique**

The Delphi Technique is very useful in situations where the judgments of individuals must be tapped and combined to address a lack of agreement or incomplete state of knowledge (Delbecq et al. 1975). Delphi is particularly valued for its ability to structure and organize group communication (Powell, 2003). Highly significant is the fact that the Delphi technique documents facts and opinions of the panelists, while avoiding the pitfalls of face-to-face interaction, such as group conflict and individual dominance (Gupta and Clarke 1996). It is an inexpensive research methodology involving experts

without physically bringing them together. Masser and Foley (1987) added that the use of controlled feedback and anonymity from experts helps panelists to revise their views without publicly admitting that they have done so, thus encouraging them to take up a more personal viewpoint rather than a cautious institutional position. The Delphi approach offers an additional advantage in situations where it is important to define areas of uncertainty or disagreement among experts. In these instances, Delphi can highlight topics of concern and evaluate uncertainty in a quantitative manner. Group evaluation of belief statements made by panel members is an explicit part of Delphi (Robinson, 1991).

The major difficulties of Delphi, however, lie in maintaining the high level of response and in reaching and implementing a consensus (Robinson 1991). The study also takes a long time and considerable effort to be complete (De Loe 1995) and the effects of pressures for conformity to build consensus in Delphi studies may produce inaccurate conclusions about participant opinions (Woudenberg 1991). However, this notion was disputed “the value of the Delphi method is not in reporting high reliability consensus states, but rather in altering the participants to the complexity of issues by forcing, cajoling, urging, luring them to think, by having them challenge their assumptions” (Coates 1975).

Based on the strengths and limitations of the Delphi technique, seven suggestions are provided to minimize problems faced when conducting Delphi surveys (Ali 2005):

1. The use of broad questions in the first round of the Delphi survey may discourage participants who have time constraints; it is recommended that the questions be less broad to encourage full participation.
2. Participants should be given sufficient time to complete each round of the survey to ensure that there is enough time to think and provide responses without pressure due to time constraints.

3. Follow-ups are critical to maintain a high response rate throughout the rounds of the survey. Researchers should not be discouraged by low response rates to Delphi rounds.
4. Providing incentives (e.g., monetary, certificates of appreciation from a major institution, and gifts) to contributors to a Delphi study will encourage more experts to participate and respond promptly to Delphi round questionnaires.
5. E-mail communication is a fast, cheap and effective means for conducting Delphi surveys. However, technical communication problems in many countries may be a hindrance to the use of e-mail and other methods of communication such as fax, phone calls, or regular mail may be considered.
6. Adopting majority voting as a means to analyze responses to Delphi rounds would produce reliable findings and demonstrate controversial issues, especially in large panels.
7. Categorizing responses to Delphi surveys (e.g., legal authority, relative autonomy, levels of control, and capacity) enables the researcher to summarize responses to round questionnaires. That can help the analyst summarize responses to Delphi rounds when participants have diverse expertise and provide a wide range of valid responses.

The Delphi method can be used effectively to structure group communication within a limited time. If study protocol is designed appropriately taking into consideration the most salient features of the Delphi and the tips for conducting the rounds, the use of the method can yield very successful results.



**Summary**

Chapter III discussed potential methodologies that were considered for use to achieve the objectives of this study. Experimental methods were found to be less suitable for the purposes of this study due to the unpredictability of the relationship between contingency and the major factors that affect contingency. Non experimental methods such as surveys and the use of questionnaires on the other hand can be more useful in achieving the desired study results if well structured. However, the Delphi method combines aspects of survey techniques and questionnaire use. This chapter described successful applications of the Delphi method. From a review of past literature, the method was found to be very effective and will be used to achieve the objectives of this study.

## **CHAPTER IV**

### **DATA COLLECTION PROTOCOL**

From the review of past literature, it was evident that SHAs apply contingency on highway projects using different methods such as predetermined percentages, unique project contingencies and risk analysis and associated contingencies. Often, the application of contingency on projects is highly subjective and methods used are not consistent with other factors such as the complexity of the project. In order to fully integrate major factors affecting contingency into the development of sliding scale contingencies, it was very important to select a method of data collection which would enable the participants to respond without time pressure and without losing motivation, the essence of the study. Participants would need to review a substantial amount of information and provide a personal assessment based on experience. At the same time, in this study it was very important to develop response protocols which would not overburden participants and reduce the validity of their responses. Some major factors which indicated that the use of the Delphi method would be advantageous are:

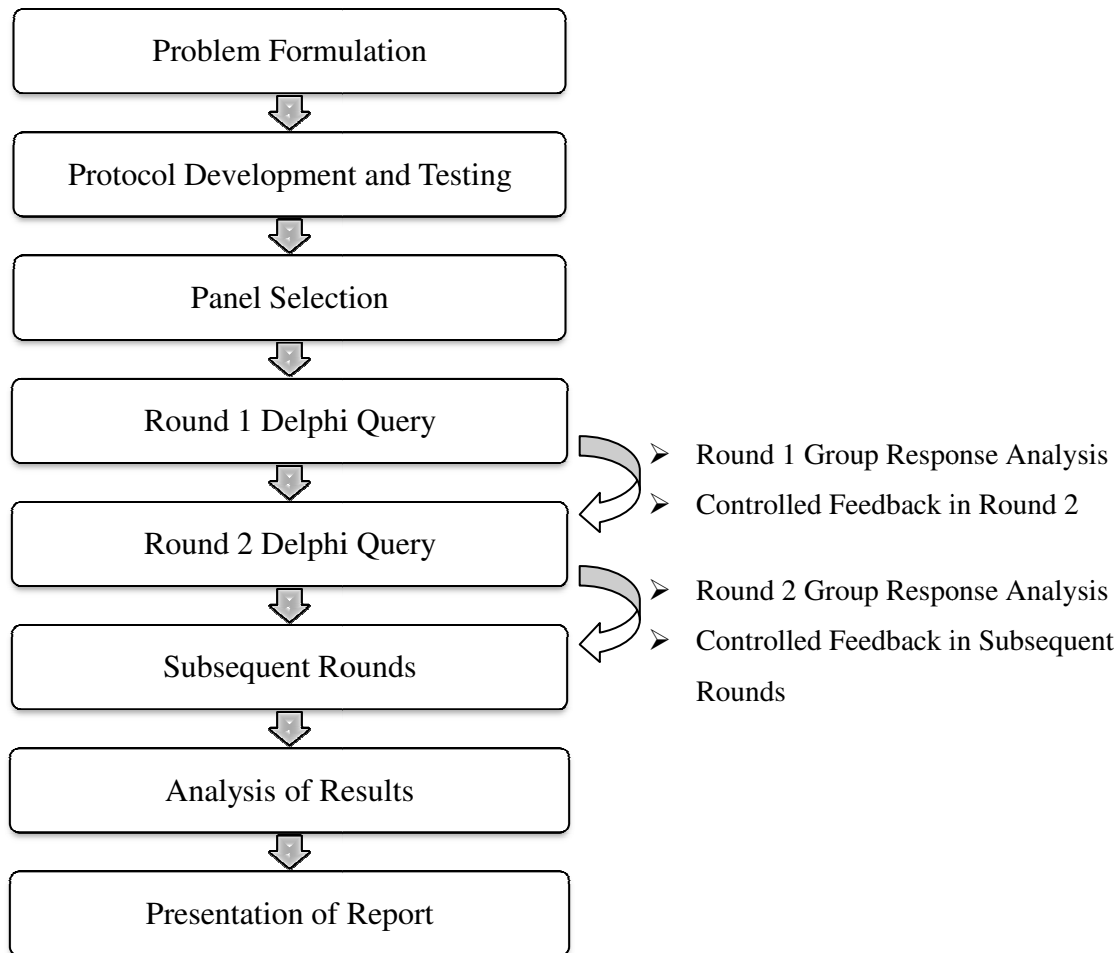
- Experimental methods were not applicable due to a lack of data.
- Experimental methods require that a predictable relationship can be established between variables. In this study it is not possible to predict an exact effect on the amount of contingency due to factors such as project complexity, estimation method, and level of scope definition at the time of estimate preparation.
- It would have been difficult to conduct face to face interviews and achieve significant results within the time frame for the study partly due to the number of participants involved.
- The best results of a subjective study such as this one are achieved when participants are not under pressure to provide responses.

- One major characteristic of the Delphi method is the use of controlled feedback to participants at the end of each round allowing participants to review the group response from all the other participants.

The Conventional Delphi approach was used to conduct this study. In contrast with the Policy Delphi, the Conventional Delphi is more suitable for this study because:

1. The study relies heavily upon the expert judgment of professionals in the Highway Industry; whereas for the Policy Delphi participants are not necessarily experts in the research topic.
2. The study aims to achieve consensus among panelists; whereas as stated by De Loe (1995) and Linstone and Turoff (2002) the Policy Delphi does not seek to build consensus but attempts to generate possible opposing views for certain policy issues.

The Delphi method was adapted to suit the purposes of this study. Figure 10 depicts the sequence of activities performed to achieve the objectives of this study.



**Figure 10: The Delphi Method**

### **Problem Formulation**

The research problem arose as a result of inconsistencies in the application of contingency on highway projects by U.S. State Highway Agencies. The problem formulation has been discussed in greater detail in Chapter I.

### **Protocol Development and Testing**

In each round, participants were required to provide an individual assessment of what contingency may be adequate for different types of projects based on complexity. The

following factors were included as a basis for the contingency assessment and will be discussed in further detail next:

- Project type/complexity
- Phase of project development
- Level of definition at the time of estimate preparation
- Estimate type and methodology

#### Project Type/Complexity

The project complexity definitions used in this study were adopted from a recent study “Guidance for Cost Estimation and Management for Highway Projects during Planning, Programming, and Preconstruction, *NCHRP 8-49 (Report 574)*.” Projects were described using attributes related to the roadway, traffic control approaches, structures, right of way, utilities, environmental requirements, stakeholder involvement and project location. Table 11 shows a few examples of the complexity classifications.

**Table 11: Examples of Complexity Classifications (Molenaar et al. 2008)**

<b>Most Complex (Major) Projects</b>	<b>Moderately Complex Projects</b>	<b>Non-complex (Minor) Projects</b>
<ul style="list-style-type: none"> <li>• New highways; major relocations</li> <li>• New interchanges</li> <li>• Capacity adding/major widening</li> <li>• Major reconstruction (4R; 3R with multi-phase traffic control)</li> <li>• Congestion Management Studies are required</li> </ul>	<ul style="list-style-type: none"> <li>• 3R and 4R projects which do not add capacity.</li> <li>• Minor roadway relocations.</li> <li>• Certain complex (non-trail enhancements) projects.</li> <li>• Slides, subsidence.</li> </ul>	<ul style="list-style-type: none"> <li>• Maintenance betterment projects</li> <li>• Overlay projects, simple widening without right-of-way (or very minimum right-of-way take) little or no utility coordination</li> <li>• Non-complex enhancement projects without new bridges (e.g. bike trails)</li> </ul>

4R is rehabilitation, restoration, resurfacing or reconstruction.

One alternative method considered was to describe three projects using as many of the defining characteristics of a highway project as possible. There would have been a one or two page description for each project types. However that method was not used because the descriptions would have been very lengthy and may have introduced ambiguity in the assessment process. Furthermore, participants who have time constraints may have been discouraged with such large volumes of documentation to read through before making their assessments.

The use of the complexity definitions arose out of a need to present participants with a scenario which would ensure consistency in the contingency assessments across the board for all participants. New projects or reconstruction projects are way more complex in terms of requirements than a simpler project such as asphalt overlay. Project location could also impact complexity significantly such as interstate or non interstate projects. More complex projects may involve the relocation of major utilities or have major right-of-way issues. For these reasons it was necessary to clearly distinguish between the three levels of complexity used in the study. The definitions in the NCHRP report 574 provided a clear and concise way to present the participants with three project complexity scenarios. Full complexity definitions are shown in Tables A-1, A-2, and A-3.

Representative risks were identified for the different project complexity scenarios and included with the complexity definitions. The list of representative risks is not exhaustive but only identifies some of the risks that may be typical in those project types. The lists of risks were provided to participants so that they would consider major risks in making their contingency assessments. Examples of representative risks are shown in Table 12. The full list of representative risks is shown in Tables A-4, A-5, and A-6.

**Table 12: Examples of Representative Risks**

PROJECT TYPE	MOST COMPLEX	MODERATELY COMPLEX	NON-COMPLEX
REPRESENTATIVE RISKS	Unresolved constructability issues	Geotechnical issues	Contractor delays
	Design complexity	Changes in materials/ foundation	Changes in program priorities
	Political factors	Delays in permitting process	Errors in cost Estimating
	Complex environmental requirements	Bridge redesign/ analysis	Inaccurate technical assumptions

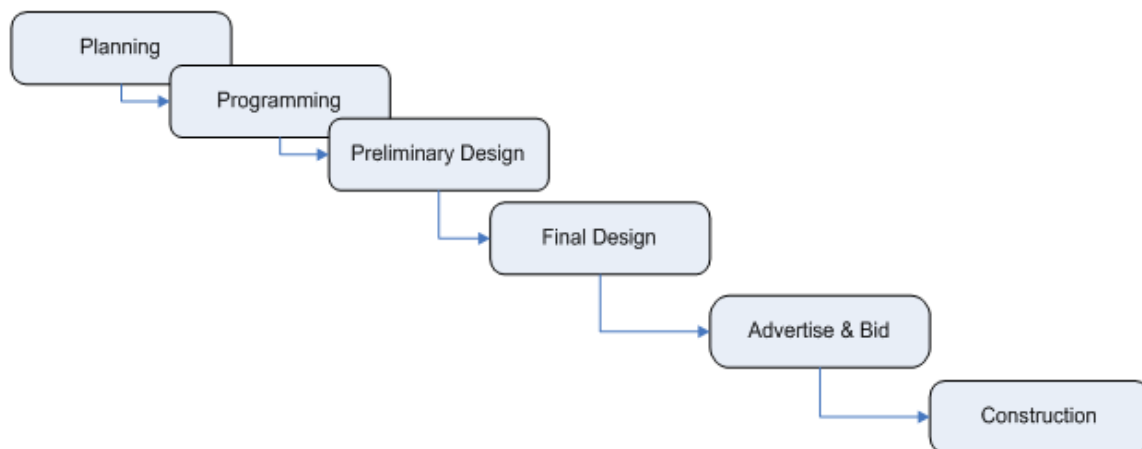
For each of the three complexity definitions participants were asked to note that project location could significantly increase the complexity of a project due to traffic control challenges, for example an interstate mainline compared to a mainline NHS routes (non-interstate) or an urban location compared to a rural location; this could significantly impact the ranges of contingency to be used on a project.

#### Phase of Project Development

State Highway Agencies describe their project development phases using slightly different terminologies. Most SHAs identify needs or major projects in the planning phase of project development which could be as long as 20 years from construction letting. Planning cost estimates are used by SHAs to support their long range plans. At this point project information is very limited since the scope is not finalized. The majority of the projects are typically not identifiable at this point; this introduces a huge amount of uncertainty in the project cost estimate. The communication of estimates using ranges effectively conveys the inherent uncertainty to stakeholders. The phase of project development when the estimate is prepared plays a very important role in determining the estimating tools and techniques that would be more applicable. As the project moves into the programming phase more of the scope is defined and early planning estimates are refined. SHAs often use programming estimates for setting

project baselines for controlling project costs. Such projects are typically included into a priority program which may be 10 years or less from construction letting. Anderson et al. (2007) stated that typically, when a project is included in the priority program, authorization is often given for preliminary design to begin. As the scope is better defined towards the end of programming most SHAs prepare the project baseline cost estimate. Not all projects in the priority program are selected for further development. Projects chosen from the priority program are included into the Statewide Transportation Improvement Plan (STIP). The STIP usually has a time horizon which is five years or less from construction letting. In the preliminary design phase, scope definition transforms from general requirements to detailed physical components. Cost estimates are revised at specific points of design completion such as 30%, 60%, and 90% and used to validate project cost against current design scope (Molenaar et al. 2008). In the final design phase of project development, the project is well defined and the plans and specifications (PS&E) are complete.

Figure 11 depicts the phases of project development used in project NCHRP 8-49. It shows the overlapping nature of the planning, programming and preliminary design phases.



**Figure 11: Project Development Phases (NCHRP 8-49)**



Table 13 shows the project development phases and the typical activities performed in each of the phases.

**Table 13: Project Development Phases and Activities (NCHRP 8-49)**

<b>DEVELOPMENT PHASES</b>	<b>TYPICAL ACTIVITIES</b>
<b>Planning</b>	Purpose and need; improvement or requirement studies; environmental considerations; right-of-way consideration; public involvement/participation; interagency conditions.
<b>Programming</b>	Environmental analysis; schematic development; public hearings; right-of-way impact; project economic feasibility and funding authorization.
<b>Preliminary Design</b>	Right-of-way development; environmental clearance; design criteria and parameters; surveys/utility locations/drainage; preliminary plans such as alternative selections; geometric alignments; bridge layouts.
<b>Final Design</b>	Right-of-way acquisitions; PS&E development-final pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, final cost estimates.
<b>Advertise and Bid</b>	Prepare contract documents, advertise for bid, hold a pre-bid conference, and receive and analyze bids.
<b>Construction</b>	Determine the lowest responsive bidder; initiate contract; mobilize; conduct inspection and materials testing; administer contract; control traffic; and construct bridge, pavement, and drainage.

In this study, participants were required to assess the owner construction contingency that would be included in the estimates up to the final design phase just before the project is bid. For consistency, the descriptions of the phases of project development used in this study are adopted from the NCHRP 8-49 (Report 574) project. The following definitions were used in conducting the Delphi query:

- **Planning:** The project development phase that includes identifying and assessing transportation system needs, developing the initial design concept and scope of projects that would address those needs, crafting project purpose and need, considering environmental factors, facilitating public involvement/participation, and considering a proposed project in the larger context of the transportation system and the affected community. In this phase of project development early estimates are typically prepared to support funding decisions and can be

communicated as deterministic or range estimates due to the incompleteness of the scope.

- **Programming/ Preliminary Design:** The project development phase that includes conducting environmental analysis, conducting schematic development, holding public hearings, determining right-of-way impact, determining project economic feasibility, obtaining funding authorization, developing right-of-way needs, obtaining environmental clearance, determining design criteria and parameters, surveying utility locations and drainage, and making preliminary plans such as alternative selections, assign geometry, and create bridge layouts. Early programming estimates are similar in purpose to planning estimates. However, later in the programming phase when the scope definition is improved project estimates are prepared for setting baselines and for project controls.
- **Design:** The project development phase that includes acquiring right-of-way; developing plans, specifications, and estimates (PS&E), that is, finalizing pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, and cost estimates.

#### Level of Definition at the Time of Estimate Preparation

In the planning phase of project development project scope definition is very low because of the limited project information available. The project definition improves as the project moves from planning through programming to preliminary design and final design phase of project development. When the project definition is lowest, such as in the planning phase, estimates prepared at that time have a high amount of uncertainty. This is because majority of the project risks have not been identified due to incomplete definition of the project scope. In the later phases of project development the uncertainty decreases as the scope becomes better defined. Typically the contingency included in planning estimates is much higher than in the design phases to account for the high level of uncertainty. Typically the level of scope definition is around 90% at the final design phase. However, depending on the complexity of a project, levels of scope definition in

the earlier phases of project development (such as planning) may vary between zero and fifteen percent. AACEI developed a generic cost estimate classification system for use across different industries (Table 14). The AACEI estimate classes labeled 1, 2, 3, 4 and 5 are categorized by level of project definition, estimate purpose, estimating method, and preparation effort and time. According to Christensen et al. (1997) those are the most significant characteristics used to categorize cost estimates. A class 5 estimate is based on the lowest level of project definition (0% to 2%) while a class 1 estimate is based on a high level of definition which is close to full project definition (50% to 100%). A class 5 estimate is used in early planning or project feasibility and estimating methods are typically stochastic since the level of scope definition is still very low (0% to 2%). The expected accuracy range (4 to 20) for a class 5 estimate is a measure of the final project cost accuracy compared to the estimated cost, it is not a percentage accuracy but an index value relative to a best value of 1. For instance if a class 1 estimate (expected accuracy range of 1) in a particular industry is +10/-5, then a class 5 estimate (expected accuracy range of 4 to 20) in the same industry may be anywhere between +40/-20 percent to +200/-100 percent. Estimate preparation effort is an indication of cost, time and resources, and the effort will typically increase with an increasing number and complexity of the project definition deliverables that are produced (Christensen et al., 1997).

**Table 14: AACEI Generic Cost Estimate Classification System  
(Christensen et al., 1997)**

	Primary Characteristic	Secondary Characteristics			
<b>ESTIMATE CLASS</b>	<b>LEVEL OF PROJECT DEFINITION</b> Expressed as % of complete definition	<b>END USAGE</b> Typical purpose of estimate	<b>METHODOLOGY</b> Typical estimating method	<b>EXPECTED ACCURACY RANGE</b> Typical +/- range relative to best index of 1 [a]	<b>PREPARATION EFFORT</b> Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or feasibility	Stochastic or judgment	4 to 20	1
Class 4	1% to 15%	Concept study or feasibility	Primarily stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget authorization, or control	Mixed, but primarily stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or bid/ tender	Primarily deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check estimate or bid/ tender	Deterministic	1	10 to 100

Notes:

[a] If the range index value of “1” represents +10/-5%, then an index value of 10 represents +100/-50%

[b] If the cost index value of “1” represents 0.005% of project costs, then an index value of 100 represents 0.5%

Table 15 shows the cost estimate classification system used by Washington State Department of Transportation (WSDOT) (Molenaar et al. 2008). The WSDOT cost estimate classification system is based on the generic cost estimate classification system developed by AACEI. The level of definition varies between zero and fifteen percent in planning, while in programming the scope definition is between ten and thirty percent. In

the design phase the definition varies between thirty and ninety percent, and in final design between ninety and a hundred percent. WSDOT cost estimate classification also shows the purpose of such estimates like the planning estimate which is only used for conceptual planning since the scope is not finalized yet at that point.

**Table 15: WSDOT Cost Estimate Classification System (Molenaar et al. 2008)**

PROJECT DEVELOPMENT PHASE	PROJECT MATURITY (% PROJECT DEFINITION COMPLETED)	PURPOSE OF THE ESTIMATE	ESTIMATING METHODOLOGY	ESTIMATE RANGE
<b>Planning</b>	0 to 2%	Conceptual Estimating – Estimate Potential Funds Needed (20-year plan)	Parametric (Stochastic or Judgment)	-50% to +200%
	1% to 15%	Conceptual Estimating – Prioritize Needs for Long Range Plans (HIP – 10-year plan)	Parametric or Historical Bid-Based (Primarily Stochastic)	-40% to +100%
<b>Scoping (Programming)</b>	10% to 30%	Design Estimating – Establish a Baseline Cost for Project and Program Projects (HIP and STIP)	Historical Bid-Based or Cost-Based (Mixed, but Primarily Stochastic)	-30% to +50%
<b>Design</b>	30% to 90%	Design Estimating – Manage Project Budgets Against Baseline (STIP, Contingency)	Historical Bid-Based or Cost-Based (Primarily Deterministic)	-10% to +25%
<b>Final Design</b>	90% to 100%	PS&E Estimating – Compare with Bid and Obligate Funds for Construction	Cost-Based or Historical Bid-Based Using CES. (Deterministic)	-5% to +10%

The levels of project scope definition used for the purpose of this study were similar to the WSDOT cost estimate classification but vary by project complexity as will be shown in the matrix descriptions for the query. The following definition was used in conducting the Delphi query:

- **Level of Definition:** A description of project construction requirements and attributes to include technical and site related information (often referred to as the project scope). The level of definition increases from the planning phase to the final PS&E phase of Project Development. At one extreme, early planning estimates are defined only by major parameters (1 to 5 percent complete definition), while at the other extreme, the plans and specifications are complete (100 percent).

Table 16 shows the level of definition for the project development phases used in the Delphi query protocol for the assessment of contingencies.

**Table 16: Project Development Phase and Level of Definition**

<b>Non-Complex (Minor)</b>		<b>Moderately Complex</b>		<b>Most Complex (Major)</b>	
<b>Project Development Phase</b>	<b>Level of Definition</b>	<b>Project Development Phase</b>	<b>Level of Definition</b>	<b>Project Development Phase</b>	<b>Level of Definition</b>
Planning	1-3%	Planning	4-7%	Planning	7-15%
Programming	5-15%	Programming	15-25%	Programming	15-35%
Design 1	15-40%	Design 1	25-35%	Design 1	35-75%
Design 2	40-70%	Design 2	35-70%	Design 2	75-100%
Design 3	70-100%	Design 3	70-100%		

#### Estimate Type and Methodology

Planning estimates are usually order-of-magnitude cost estimates used to support the state highway agencies' long range plans. Such estimates are fraught with a great deal of uncertainty which needs to be effectively communicated to stakeholders. Planning

estimates are prepared using conceptual estimating techniques due to the low level of scope definition at that point in the project life cycle. Some SHAs include a predetermined percentage of the project cost to cover unknown risks at this point. The percentage may be determined by establishing relationships between major cost estimate parameters and historical data obtained from past projects. For instance an estimator may obtain the unit cost of a major parameter (or cost per lane mile of highway) from historical data and then multiply by the estimated quantities for the current project (number of lane miles) to derive an estimated cost for that parameter in the budget. One of the most effective ways to communicate ranges in the planning phase is by the use of ranges to reflect the amount of uncertainty in the estimate. A wider cost range indicates a greater amount of uncertainty. Cost ranges narrow as projects progress through project development.

Programming cost estimates are a refinement of the planning estimate due to improved scope definition. Programming estimates are typically used to set the baseline estimate for the project. Most SHAs use estimates developed late in the programming phase for managing costs in subsequent phases of project development. Historical bid-based estimation techniques are often used in combination with percentages due to the availability of only limited project information (Anderson et al. 2007). At this point in project development some SHAs identify major risks and prepare a risk management plan and risk register which are updated throughout the project life cycle.

Once preliminary design starts, the programming estimate becomes the project base estimate against which estimates prepared in the design phase of project development are measured. Estimating techniques used in the preliminary design phase may involve comparison with recent bids to determine appropriate estimates for major line items already identified. As project scope definition improves more of the major line items become identified until all items can be identified at full scope definition. Further risk identification efforts and risk updating for mitigated risks should reduce the amount of

uncertainty in the project estimates and therefore reduce the need for a higher contingency. However, if updated baseline estimates significantly exceed the project baseline SHAs examine the estimates for any discrepancies. Typically, the contingency added to the baseline estimate in this phase is less than the contingency in the planning and programming estimates. Molenaar et al. (2008) pointed out that management uses estimate updates to evaluate scope changes and other issues that affect the project cost.

In the later design and final design phases of project development, the project is well defined. The majority of line items have been identified and cost estimates are usually include less uncertainty. Project risks identified in the earlier phases of project development have either not occurred, been mitigated or still being monitored. Contingency required in the later design phases is usually minimal. At the final design phase when the plans, specifications and estimates are complete, the project is already well defined and any construction related risks are embedded into the project line or pay items in the engineers estimate (Molenaar et al. 2008). The estimate types and classifications described in the previous paragraphs were summarized for use in the Delphi query as follows:

- Planning - Parametric estimating where costs are estimated using major project parameters such as lane miles, square foot of bridge deck area, and percentage of construction cost.
- Programming - Bid based estimating where major items are identified (80% of costs in 20% of items) in combination with some cost based estimating and percentages.
- Design - Bid based estimating where most items are identified as the design is prepared in combination with some cost based estimating and percentages.
- PS & E - Bid based and/or cost based estimating where all items (pay) are identified.



### Other Definitions

The following are some other definitions that were used in this study to ensure consistency in the assessment parameters used by the participants:

**Base Estimate:** The base estimate is defined as the most likely project estimate, exclusive of Project Contingency, for known costs for all known construction work.

**Contingency:** An estimate of costs associated with identified uncertainties and risks, the sum of which is added to the Base Estimate to complete the Project Cost Estimate. Contingency is expected to be expended during the project development and construction process.

**Historic Data:** Cost estimates are based on historic data. The nature of this historic data is often different depending on the estimate types. Historic contractor bids captured by the DOT are used to support bid based estimating. Past similar project unit cost data is often used to support bid based estimating when the past project is very similar to the project being estimated. Specific categories of data are used to support cost based estimating including crew sizes and wage rates, crew production rates, material costs, equipment production rates and costs, and contractor overhead and profit costs. Percentages to support allowances are often based on past projects using a similar set of bid items that cover an element of work (e.g., drainage).

### Matrix Description

A matrix was developed to include all the assessment factors described for each of the three project types. The matrix (Table 17) formed the basis for assessment of contingency in this study using the Delphi technique.

**Table 17: Matrix Descriptions**

Project Type/ Complexity	No. of Phases	Phase of Project Development	Phase Description	Level of Definition	Estimate Type	Historic Data
<b>Non-Complex (Minor)</b>	<b>5</b>	Planning	10 to 20 yrs from letting	1 - 3%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	5 - 15%	Bid based (80/20 rule) with other	Recent Bids, Past Projects
		Design 1	4 yrs or less from letting	15 - 40%	Bid based with 75% line items identified	Recent Bids
		Design 2	less than 4 yrs from letting	40 - 70%	Bid based with 90% Line items identified	Recent Bids
		Design 3	less than 4 yrs from letting	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs
<b>Moderately Complex</b>	<b>5</b>	Planning	10 to 20 yrs from letting	4 - 7%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 25%	Bid based (80/20 rule) with other	Recent Bids, Past Projects
		Design 1	4 yrs or less from letting	25 - 35%	Bid based with 75% line items identified	Recent Bids
		Design 2	less than 4 yrs from letting	35 - 70%	Bid based with 90% Line items identified	Recent Bids
		Design 3	less than 4 yrs from letting	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs
<b>Most Complex (Major)</b>	<b>4</b>	Planning	10 to 20 yrs from letting	7 - 15%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects
		Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 35%	Bid based (80/20 rule) with other	Recent Bids, Past Projects
		Design 1	less than 4 yrs from letting	35 - 75%	Bid based with 80% Line items identified	Recent Bids
		Design 2	less than 4 yrs from letting	75 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs

The Delphi protocol was prepared using the information described in this section. Email was used as the primary means of communication. All information was provided to the participants using an excel spreadsheet. Each tab in the spreadsheet was described in detail and contained all the information that participants would require to complete the assessment. The spreadsheet for each subsequent round contained some additional information/feedback from the previous round. The spreadsheets will be described in detail in sections following. The spreadsheet was tested by three experts and it was found that it would take about 45 minutes to an hour to read through the material provided and complete the assessment.

### **Panel Selection**

Potential participants were selected from research panels on past highway projects, professionals on past NCHRP projects, technical committees on cost estimating, state highway agencies and from academics involved in highway research. Panel members were invited to participate using one or more of the following criteria:

1. That they work in or are involved in highway projects within the US transportation industry.
2. That they possess a minimum of 5 years of relevant experience in project cost estimating and/or risk assessment or high exposure to such practices if less than 5 years experience.
3. That they are involved in highway related research either as academics or non academics.

A database was compiled to include members of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Design, Technical Committee on Cost Estimating (TCCE); over 90 other professionals that work in the transportation industry were also included in this database. Using names from the database, invitation letters (Appendix B - Letter of Invitation to Participants) were sent by email to 75 potential participants providing them with a brief background of the study and the methodology of assessment to be used in the study. The package also included a

response form (Appendix B – Participant Information form) on which to indicate their willingness to participate. Participants were also required to provide basic information about their professional background with emphasis on estimating and risk assessment to ascertain that they possessed relevant professional experience to be able to make accurate judgments. A total of 23 professionals agreed to participate in the study and made up the panel of experts for the Delphi rounds. The panel members represented a diverse base of relevant knowledge in the highway industry - project managers, project engineers, risk coordinators, project cost estimators, construction managers and highway program managers.

All the participants had an average of five years experience in estimating and/or risk assessment; some had experience in either of the two. Nineteen of the participants had levels of experience between one and twenty years in estimating with the majority having over ten years experience. A few participants had over twenty years experience. The average number of years of experience for the participants in risk assessment was five years; some had between sixteen and thirty years of experience. More than twelve of the participants had between five and fifteen years of experience in their areas of primary assignment such as roadway, interstate, hydraulic and bridge design, or design management. Levels of experience in Construction or Construction Management varied between two to fifteen years in each case for eleven of the participants. Some of the other areas of primary responsibility of the participants included project development and management, program risk management, contract letting, planning, engineering and management of materials with levels of experience between one and fifteen years in most cases. Table 18 summarizes the participants' level of experience in number of years by area of primary responsibility.

Follow-up emails (Appendix B – Invitation Follow-Up Letter) were sent to the 23 panel members thanking them for agreeing to participate and reemphasizing the importance of their expert judgment to the outcome of this study. They were also provided with a start date for the round 1 query.

**Table 18: Panel Profile**

Primary Responsibility Category	Sub Category of responsibility	Number of years of experience							Number of panelists with expertise in each category
		1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	
Consultancy		1							1
Construction	Construction crew, construction engineering	5	1	1					7
Design	Roadway, interstate, bridge, hydraulic	4	4	4					12
Project estimation		1							1
Design management		2	1						3
Construction management		1	2	1					4
Cost estimating		3	2	2					7
Project development/ delivery	Project delivery, development support	2	1	1					4
Project management	Project management training, project oversight	4	1			1			6
Planning		1							1
Bridge construction		1							1
Traffic engineering		1	1						2
Program risk management		2							2
Engineering				1					1
Contract management		1	1						2
Consultant management		1							1
Program management		1							1
<b>Mandatory Experience</b>									
	Risk assessment	16	1	3	1	1	1		23
	Cost estimating	5	5	5	4	1	1	2	23

Immediately after the panel selection the following steps were performed for the Delphi query:

1. Round 1 query was conducted via email. In round 1, in each subsequent round and for each project scenario, the assessment of contingency was based on the following:
  - Project Complexity – Non Complex (Minor), Moderately Complex, and Most Complex (Major).
  - Phase of Project Development – Planning, Programming/Preliminary design, and final design.
  - Level of Project Definition at time of estimate preparation.
  - Type of Estimate and estimating methodology.
2. The panel's contingency assessments in round 1 were analyzed using basic statistical techniques.
3. Summary of results in (2) were presented to the panel of experts in a subsequent round of assessment. Panelists were given an opportunity to review their initial response based on the summary of the group response in (2) above.
4. Steps (1) – (2) were repeated for the 2<sup>nd</sup> round and 3<sup>rd</sup> round.
5. Finally, the group results from the final (3<sup>rd</sup>) round were summarized, conclusions were drawn, and the preliminary results were provided to the panel members.

### **Round 1 Query**

In round 1, information was presented to the participants using an excel spreadsheet containing five sections: (1) Background and Instructions; (2) Method; (3) Project Complexities; (4) Key Definitions; (5) Contingency Matrices. Figure 12 is a screen capture of the tabs on the round 1 excel spreadsheet and the descriptions follow next.

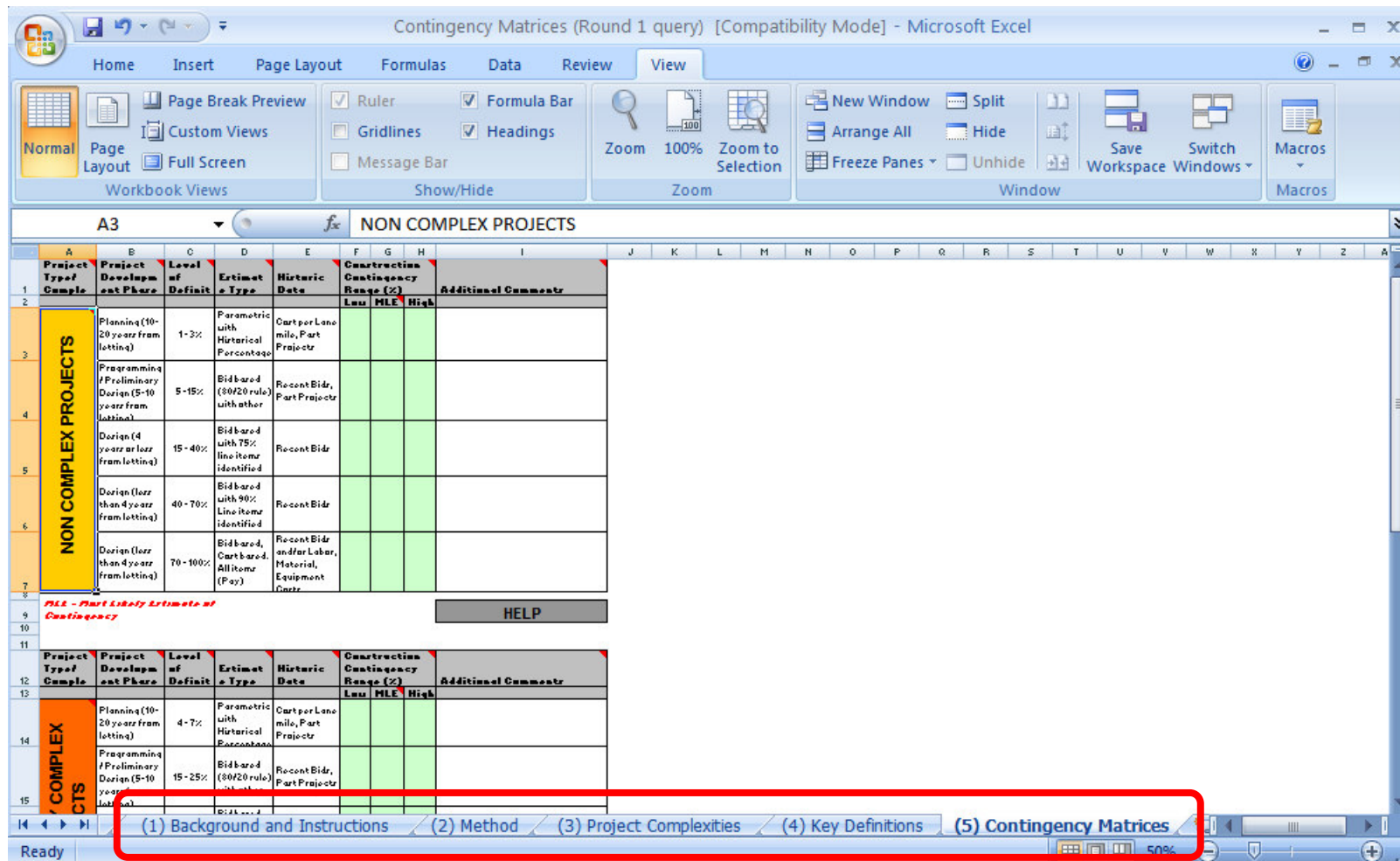


Figure 12: Round 1 Excel Spreadsheet Showing Information Tabs

### Section 1: Background and Instructions

This section included a brief background of the study and instructions for round 1 (Appendix C – Background and Instructions, Round 1). Participants were provided with three contingency matrices: one for minor projects, the second for moderately complex projects, and the third for major projects. In these matrices provisions were made to input three values of construction contingency for each phase of project development described; a low, a most likely estimate (MLE), and high value based on expert judgment. Participants were asked to fill in ranges of contingency values for construction cost estimates corresponding to the outlined phases of project development and the particular level of complexity and project definition. Participants were also provided a list of key terms used in the study. The spreadsheet contents would be described in greater detail in Section 5 of the excel spreadsheet.

### Section 2: Method

This section included a brief overview of the Delphi process highlighting some of its key features and advantages (Appendix C – Method description). The process was also described in respect to its application in this study. The Delphi technique was used because of the subjective nature of this study; opinions could not be sought using other empirical techniques.

### Section 3: Project Complexities

Participants were provided with project complexity scenarios for each project type shown in Table 11 (Examples of Complexity Classifications) and Tables A-1, A-2, and A-3 (Project Complexity Definitions) (Anderson et al. 2007). These project complexities were three fold: for Non-complex (Minor) projects, for Moderately Complex projects, and for Most Complex (Major) projects. Each of the scenarios was described by:

- Roadway types / project scope
- Traffic control issues on project
- Types or complexity of structures required



- Right of Way issues
- Utilities issues
- Environmental Impact
- Stakeholder Involvement or coordination

An additional statement was added for each project type/complexity stating that project location could significantly increase the complexity of a project due to traffic control challenges, for example an interstate mainline versus mainline NHS routes (non-interstate) or an urban location versus a rural location.

In addition to the complexity scenarios, Participants were also provided with lists of representative risks (Tables A-4, A-5, and A-6 – Representative Risks) for each project type. The lists do not represent all the possible risks within those project scenarios, but only a few major risks that could be characteristic of those project types/complexities.

#### Section 4: Key Definitions

Some of the key terms used in this study were defined for clarity and included in the round 1 package. The terms (Appendix C – Key Definitions) include planning, programming/preliminary design, level of project definition, base estimate, contingency, historic data and estimate type.

#### Section 5: Contingency Matrices

This section contains three matrices for round 1, one for each project type/complexity. The respondents were requested to input appropriate contingency ranges using their expert judgment. Each matrix was primarily described by the complexity, the number of project development phases, the level of scope definition, the estimate, and the historic data used in that phase.

By project complexity, there are three types:

- Non-complex (minor) projects
- Moderately complex projects
- Most complex (major) projects

By phase of project development, there are five (5) for Non complex and moderately complex Projects and four (4) phases for most complex projects as shown in the matrix descriptions (Table 17). The most complex projects category was described using four (4) phases of project development due to the higher level of project definition (15 – 35%) in the programming/ preliminary design phase. Major projects with many complex design features and unique project risks are often defined to a greater extent earlier on in project development to facilitate the decision making process with regard to the project and its alternatives. Also, typically estimates set in the programming phase become the project baseline against which estimates prepared in design phases of project development are compared. If the baseline scope of a major project does not achieve a higher level of definition in the programming phase future estimates may be much higher than the baseline estimate. If majority of the project risks that could have severe cost implications are not identified until after the programming phase of project development that could further increase the project estimate above the baseline. This could cause serious cost control issues for the project if it is being managed against a deficient baseline estimate. Furthermore, for this study the programming phase and preliminary design phase were merged since activities performed in those two phases overlap significantly. Performing preliminary design activities along with programming activities, according to the classification, means that a higher level of project definition will be achieved. The same classification was used in the matrix for the other project complexities.

Based on the matrix descriptions (Table 17) and on the other factors described, participants were required to provide, using their expert judgment, an estimate of the appropriate contingency ranges in the round 1 matrices shown in Tables 19 to 21. Additional spaces were provided within the matrices for participants to provide comments supporting their input (contingency ranges).

When the protocol was developed, the excel spreadsheets were tested for consistency by three professionals from the highway industry. The feedback received indicated that it would take approximately 45 minutes to an hour to complete the assessment and that it was recommended that ranges be used to express the level of scope definition rather than deterministic values. The round 1 spreadsheet was revised accordingly and sent out to the 23 participants who agreed to participate in the study with a letter of transmittal (Appendix C – Transmittal, Round 1) containing instructions for completing the spreadsheet. The participants were allowed two weeks to return the spreadsheets complete with their assessments. Fifteen assessments were received by the expiration of the two week period. A first reminder (Appendix C – First Reminder, Round 1) was sent out to the eight participants who had not returned their completed assessments and another five responses were received within a week. A second reminder (Appendix C – Second Reminder, Round 1) was sent out to the remaining three participants who had not responded. Eventually, responses were received from all 23 participants who made up the expert panel.

**Table 19: Round 1 Contingency Matrix (Non Complex Projects)**

Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Additional Comments
					Low	MLE	High	
<b>NON COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	1 - 3%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects				
	Programming/ Preliminary Design (5-10 years from letting)	5 -15%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				
	Design 1 (4 years or less from letting)	15 - 40%	Bid based with 75% line items identified	Recent Bids				
	Design 2 (less than 4 years from letting)	40 - 70%	Bid based with 90% Line items identified	Recent Bids				
	Design 3 (less than 4 years from letting)	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				

**MLE = Most Likely Estimate of Contingency**

**HELP**

**Table 20: Round 1 Contingency Matrix (Moderately Complex Projects)**

Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Additional Comments
					Low	MLE	High	
<b>MODERATELY COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	4 - 7%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects				
	Programming/ Preliminary Design (5-10 years from letting)	15 - 25%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				
	Design 1 (4 years or less from letting)	25 - 35%	Bid based with 75% line items identified	Recent Bids				
	Design 2 (less than 4 years from letting)	35 - 70%	Bid based with 90% Line items identified	Recent Bids				
	Design 3 (less than 4 years from letting)	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				

*MLE = Most Likely Estimate of Contingency*

**HELP**

**Table 21: Round 1 Contingency Matrix (Most Complex Projects)**

Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Additional Comments
					Low	MLE	High	
<b>MOST COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	7 - 15%	Parametric with Historical Percentages	Cost per lane mile, Past Projects				
	Programming/Preliminary Design (5-10 years from letting)	15 - 35%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				
	Design 1 (less than 4 years from letting)	35 - 75%	Bid based with 80% Line items identified	Recent Bids				
	Design 2 (less than 4 years from letting)	75 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				

*MLE = Most Likely Estimate of Contingency*

**HELP**

## **Round 2 Query**

The round 2 query was conducted using an excel spreadsheet similar to the round 1 spreadsheet but it contained 7 sections instead of 5.

Section 1: Background and Instructions (*New*)

Section 2: Method (*Same as round 1*)

Section 3: Project Complexities (*Same as round 1*)

Section 4: Key Definitions (*Same as round 1*)

Section 5: Group Summary Statistics (*New*)

Section 6: Respondents' Comments (*New*)

Section 7: Contingency Matrices (*New*)

The background and instructions section contained the study background information and a different set of instructions for round 2. The method description, project complexities, and key definitions remained the same. Group summary statistics and respondents' comments from round 1 were added. The matrices for round 2 were different from the round 1 matrices. They contained each participant's assessment from round 1 as well as the group assessment. Figure 13 shows the round 2 excel spreadsheet with emphasis on the tab descriptions.

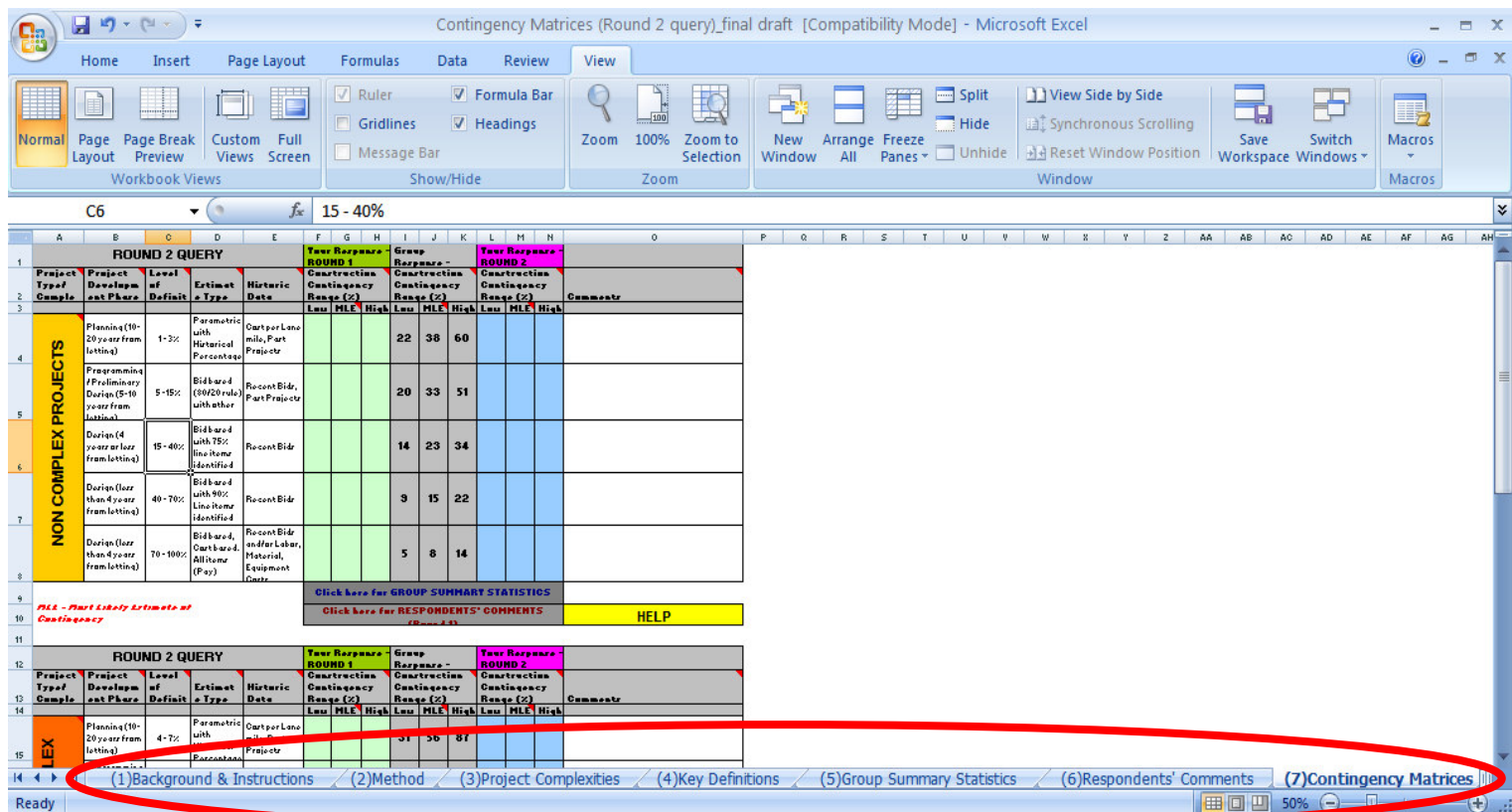


Figure 13: Round 2 Excel Spreadsheet Showing Information Tabs



### Section 1: Background and Instructions (*New*)

Similar to the round 1 background and instructions this section included a brief background of the study and instructions for round 2 (Appendix D – Background and Instructions, Round 2). Participants were provided with three contingency matrices: one for minor projects, the second for moderately complex projects, and the third for major projects. The matrices provided contained each participant's response to the round 1 query and a summary of the group response for the round 1 query. Additional space was provided for a response to the round 2 query. Based on the results of the round 1 query participants were required to revise their initial response. Participants' comments from the first round about the contingency ranges were included in a separate tab in the round 2 excel spreadsheet as part of the round 1 group response. All were asked to provide specific comments supporting their round 2 input whether they chose to alter or maintain their initial responses.

### Section 2: Method (*Same as round 1*)

This section includes a brief overview of the Delphi process highlighting some of its key features and advantages (Appendix C – Method Description). It is exactly as in the round 1 query.

### Section 3: Project Complexities (*Same as round 1*)

Participants were provided with project complexity scenarios for each project type exactly as in the round 1 query (Tables A-1, A-2, and A-3 – Project Complexity Definitions). In addition to the complexity scenarios, participants were also provided with lists of representative risks (Tables A-4, A-5, and A-6 – Representative Risks) for each project type.

### Section 4: Key Definitions (*Same as round 1*)

This section is identical with the key definitions section in round 1 and it includes some of the key terms used in this study defined for clarity (Appendix C – Key Definitions).

#### Section 5: Group Summary Statistics (New)

Participants were provided with a summary of the group response from the round 1 query. The summary statistics included means, medians, variances and the ranges for the low, MLE and High values of contingency for each project type within the phases of project development. The variances and data ranges were provided so that participants would know the spread of the contingency values input by all the participants while the means and medians showed the central tendency of the data. Summary statistics will be discussed in detail in Chapter IV.

#### Section 6: Respondents' Comments (New)

Some participants provided comments supporting the ranges of contingency specified as shown in Table D-1 – Respondents' Comments from Round 1. The comments primarily included information about major items/elements that are included in the contingency specified, and information about uncertainties/factors that could affect the ranges of contingency allowed in their projects organization. Comments will be addressed in greater detail in Chapter V.

#### Section 7: The Contingency Matrices (New)

This section contained three matrices, one for each Project Type/Complexity. As in round 1 each matrix was primarily described by the complexity, project development phases, level of scope definition at the time of estimate preparation, and estimate type and methodology. By Phase of Project Development, there are five (5) for Non complex and moderately complex Projects and four (4) phases for Most Complex Projects as shown in the round 2 matrices (Tables 22 to 24).

**Table 22: Round 2 Contingency Matrix (Non Complex Projects)**

ROUND 2 QUERY					Your Response - ROUND 1			Group Response - ROUND 1			Your Response - ROUND 2			
Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)			Comments
					Low	MLE	High	Low	MLE	High	Low	MLE	High	
<b>NON COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	1 - 3%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects				22	38	60				
	Programming/ Preliminary Design (5-10 years from letting)	5 -15%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				20	33	51				
	Design 1 (4 years or less from letting)	15 - 40%	Bid based with 75% line items identified	Recent Bids				14	23	34				
	Design 2 (less than 4 years from letting)	40 - 70%	Bid based with 90% Line items identified	Recent Bids				9	15	22				
	Design 3 (less than 4 years from letting)	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				5	8	14				
<a href="#">Click here for GROUP SUMMARY STATISTICS</a>														
<a href="#">Click here for RESPONDENTS' COMMENTS (Round 1)</a>														<b>HELP</b>

*MLE = Most Likely Estimate of Contingency*

**Table 23: Round 2 Contingency Matrix (Moderately Complex Projects)**

ROUND 2 QUERY					Your Response - ROUND 1			Group Response - ROUND 1			Your Response - ROUND 2			
Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)			Comments
					Low	MLE	High	Low	MLE	High	Low	MLE	High	
MODERATELY COMPLEX PROJECTS	Planning (10-20 years from letting)	4 - 7%	Parametric with Historical Percentages	Cost per Lane mile, Past Projects				31	56	87				
	Programming/ Preliminary Design (5-10 years from letting)	15 - 25%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				27	44	66				
	Design 1 (4 years or less from letting)	25 - 35%	Bid based with 75% line items identified	Recent Bids				19	30	46				
	Design 2 (less than 4 years from letting)	35 - 70%	Bid based with 90% Line items identified	Recent Bids				13	21	30				
	Design 3 (less than 4 years from letting)	70 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				7	12	19				
					Click here for GROUP SUMMARY STATISTICS									
					Click here for RESPONDENTS' COMMENTS (Round 1)									HELP

MLE = Most Likely Estimate of Contingency

*MLE = Most Likely Estimate of Contingency*

**Table 24: Round 2 Contingency Matrix (Most Complex Projects)**

ROUND 2 QUERY					Your Response - ROUND 1			Group Response - ROUND 1			Your Response - ROUND 2			
Project Type/ Complexity	Project Development Phase	Level of Definition	Estimate Type	Historic Data	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)			Comments
					Low	MLE	High	Low	MLE	High	Low	MLE	High	
MOST COMPLEX PROJECTS	Planning (10-20 years from letting)	7 - 15%	Parametric with Historical Percentages	Cost per lane mile, Past Projects				44	74	118				
	Programming/ Preliminary Design (5-10 years from letting)	15 - 35%	Bid based (80/20 rule) with other	Recent Bids, Past Projects				34	55	92				
	Design 1 (less than 4 years from letting)	35 - 75%	Bid based with 80% Line items identified	Recent Bids				21	34	49				
	Design 2 (less than 4 years from letting)	75 - 100%	Bid based, Cost based. All items (Pay)	Recent Bids and/or Labor, Material, Equipment Costs				12	21	33				
					Click here for GROUP SUMMARY STATISTICS									
					Click here for RESPONDENTS' COMMENTS (Round 1)									HELP

MLE = Most Likely Estimate of Contingency

*MLE = Most Likely Estimate of Contingency*

Participants were asked to review their initial assessments of contingency ranges from round 1 based on the participants' comments in section 5 and the group response provided in section 6. Based on the matrix descriptions (Table 17) and on the other information provided in sections 1 through 6, participants were requested to reevaluate their initial estimates of the appropriate contingency ranges for each level of assessment. They could either choose to maintain or modify their initial response. Additional spaces were provided within the matrices for participants to provide comments supporting their input (contingency ranges).

The round 2 spreadsheet was prepared and sent out to all 23 participants involved in the study accompanied by a letter of transmittal (Appendix D – Transmittal Round 2) containing instructions for completing the spreadsheet. The participants were allowed two weeks to return the spreadsheets complete with their assessments. After the deadline of two weeks, reminders (Appendix D – First Reminder, Round 2) were sent to eleven participants who had not responded. A second reminder was sent out with a one week deadline for response (Appendix D – Second Reminder, Round 2) by the end of which six more responses were received. A third reminder (Appendix D – Third Reminder, Round 2) was sent to the five participants who had not returned their completed assessments asking that they complete and return as soon as possible within a week to facilitate the analysis of the results of round 2. Eventually responses were received from all 23 participants.

**Round 3 Query**

In round 3, participants were given an opportunity to review their assessments from round 2. It was a consolidation round to clarify that participants were comfortable with their assessments at the end of round 2; otherwise they were given an opportunity in this round to revise their assessments. The aim of the third round was to ensure that there was consensus or stability in the results. If the majority of the participants did not change their responses or made minimal changes to their earlier assessments, it was determined from past Delphi studies that stability has been achieved; at this stage conducting any further rounds would not be meaningful. If consensus or stability has not been achieved after 3 rounds, subsequent rounds may be necessitated but may also lead to fatigue of the participants.

The round 3 query was conducted using an excel spreadsheet similar in design to the round 1 and round 2 spreadsheets though different in content. It contained three new sections. Figure 14 shows the round 3 spreadsheet with emphasis on the information tabs. The contents will be described thereafter.

Contingency\_Study\_(Round\_3\_query)\_final\_draft - Microsoft Excel

Home Insert Page Layout Formulas Data Review View

Normal Page Layout Custom Views Show/Hide Zoom 100% Zoom to Selection New Window Arrange All Freeze Panes Save Workspace Switch Windows Macros

Security Warning Automatic update of links has been disabled Options...

A4 ROUND 3 QUERY

**ROUND 3 MATRICES**

You are only required to provide values in this section if you wish to review your earlier assessment based on new information from the round 2 query. Input appropriate contingency ranges ONLY in the project categories where your round 3 assessment may differ from your earlier (round 2) assessment. Please note that if you do not wish to change your response, you only need to reply "YES" to the round 3 email received; you would NOT be required to fill out the ROUND 3 response columns in the matrices below.

ROUND 3 QUERY				Your Response - ROUND 2			Group Response - ROUND 2			Your Response - ROUND 3		
Project Type/Complexity	Project Development Phase	Level of Definition	Contingency Range (%)	Low	MLE	High	Low	MLE	High	Low	MLE	High
COMPLEX PROJECTS	Planning (10-20 years from letting)	1-3%					23	41	67			
	Programming/Preliminary Design (5-10 years from letting)	5-15%					21	34	54			
	Design (4 years or less from letting)	15-40%					16	25	38			
	Design (less than 4 years from letting)	20-100%					10	17	25			

(1) Instructions (2) Round 1 vs. Round 2 (3) Contingency Matrices

Figure 14: Round 3 Excel Spreadsheet Showing Information Tabs



### Section 1: Instructions (New)

This section included instructions for the round 3 query (Appendix E – Instructions, Round 3). Participants were provided with a comparison of summary statistics from round 1 and round 2 and were asked to indicate whether they would maintain or revise their round 2 assessments based on new information. For participants who wish to revise their round 2 assessments contingency matrices were provided with space to input their revised assessments; three contingency matrices: one for minor projects, the second for moderately complex projects, and the third for major projects. These matrices contained each participant's response to the round 2 query and a summary of the group response for the round 2 query.

### Section 2: Round 1 vs. Round 2 Statistics (New)

This section provided a comparison between the group summary statistics from round 1 and the statistics from round 2. The summary statistics showed were the means, medians, variances and the ranges for the low, MLE and High values of contingency for each project type within the phases of project development. As in round 2 the variances and data ranges were provided so that participants would know the spread of the contingency values input by all the participants while the means and medians showed the central tendency of the data.

### Section 3: The Contingency Matrices (New)

This section contained three matrices, one for each Project Type/Complexity. Each matrix was primarily described by project complexity, phase of project development, level of scope definition at the time of estimate preparation, estimate type, and the estimate methodology used in that phase. Each participant was provided with their response to round 2, the group summary results at the end of round 2, and space to input their revised (round 3) assessment for those who chose to do so. The matrices are shown in Tables 25 to 27.

**Table 25: Round 3 Contingency Matrix (Non Complex projects)**

ROUND 3 QUERY			Your Response - ROUND 2			Group Response - ROUND 2			Your Response - ROUND 3 (OPTIONAL)		
Project Type/ Complexity	Project Development Phase	Level of Definition	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)		
			Low	MLE	High	Low	MLE	High	Low	MLE	High
<b>NON COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	1 - 3%				23	41	67			
	Programming/ Preliminary Design (5-10 years from letting)	5 -15%				21	34	54			
	Design 1 (4 years or less from letting)	15 - 40%				16	25	38			
	Design 2 (less than 4 years from letting)	40 - 70%				10	17	25			
	Design 3 (less than 4 years from letting)	70 - 100%				5	9	15			
<i>MLE = Most Likely Estimate of Contingency</i>			Round 1 vs. Round 2 Statistics Compared								

**Table 26: Round 3 Contingency Matrix (Moderately Complex projects)**

ROUND 3 QUERY			Your Response - ROUND 2			Group Response - ROUND 2			Your Response - ROUND 3 (OPTIONAL)		
Project Type/ Complexity	Project Development Phase	Level of Definition	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)		
			Low	MLE	High	Low	MLE	High	Low	MLE	High
<b>MODERATELY COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	4 - 7%				32	59	93			
	Programming/ Preliminary Design (5-10 years from letting)	15 - 25%				26	43	69			
	Design 1 (4 years or less from letting)	25 - 35%				20	32	51			
	Design 2 (less than 4 years from letting)	35 - 70%				14	22	33			
	Design 3 (less than 4 years from letting)	70 - 100%				8	13	21			
<i>MLE = Most Likely Estimate of Contingency</i>			Round 1 vs. Round 2 Statistics Compared								

**Table 27: Round 3 Contingency Matrix (Most Complex projects)**

ROUND 3 QUERY			Your Response - ROUND 2			Group Response - ROUND 2			Your Response - ROUND 3 (OPTIONAL)		
Project Type/ Complexity	Project Development Phase	Level of Definition	Construction Contingency Range (%)			Construction Contingency Range (%)			Construction Contingency Range (%)		
			Low	MLE	High	Low	MLE	High	Low	MLE	High
<b>MOST COMPLEX PROJECTS</b>	Planning (10-20 years from letting)	7 - 15%				47	77	127			
	Programming/ Preliminary Design (5-10 years from letting)	15 - 35%				36	60	92			
	Design 1 (less than 4 years from letting)	35 - 75%				21	33	51			
	Design 2 (less than 4 years from letting)	75 - 100%				12	22	35			
<i>MLE = Most Likely Estimate of Contingency</i>			Round 1 vs. Round 2 Statistics Compared								

The round 3 spreadsheet was sent out to all 23 participants involved in the study accompanied by a letter of transmittal (Appendix E – Transmittal, Round 3) containing instructions for completing the spreadsheet. The participants were allowed two (2) weeks to return the spreadsheets complete with their assessments.

After the deadline of two weeks, reminders (Appendix E – First Reminder, Round 3) were sent to six participants who had not responded. It took another week after the reminders were sent out to receive the five of the six outstanding responses. A second reminder (Appendix E – First Reminder, Round 3) was sent to one participant whose response had not been received. Assessments were received from all 23 participants in this round.

### **Summary**

The data collected from the three rounds of the query were continuous data. Continuous data are data that can take on any numeric value. The data are countable and meaningful regardless of their value. There were no limits to the contingency percentages that could be provided by participants in this study. The aim of the study was to elicit an unbiased personal response from all participants on what their contingency assessments would be, given the project scenarios. The raw data collected from the participants is included in Appendix F.

Multiple reminders were sent out to participants who had not responded after the initial deadlines expired. The data collection in round 2 took about five weeks in total because three reminders had to be sent out before all responses were received. A 100% response rate was maintained in all three rounds of the study (i.e. all 23 participants responded to each round); this ensured consistency in the sample size and uniformity in the analysis of the data received.

The group responses to each round of the study were analyzed and results were reported to participants as part of subsequent rounds giving them an opportunity to reevaluate their earlier assessment based on the group response. Past studies have referred to the achievement of consensus as a major determinant of the number of rounds to be conducted in a Delphi study. This study was concluded in three rounds when stability was achieved in the responses (the majority of the participants did not make any changes to their round 2 assessments). In some past studies the mean or median was used as the feedback to participants, while the standard deviation or the variance was used as a measure of consensus. However, there were inconsistencies as to what may be considered appropriate measures of consensus. In this study the mean was used as a measure of feedback to the participants and as a measure of consensus/stability. The number of rounds was determined by the achievement of stability in the results – the point at which majority of the panel members did not significantly revise their previous responses any further even in the light of information from preceding rounds.

This chapter described the study protocol and provided an overview of the data collection process and the rounds of the Delphi study. The study results will be discussed in Chapter V and the sliding scales will also be presented.

## **CHAPTER V**

### **DISCUSSION OF RESULTS**

#### **Round 1 Query Results**

The 23 responses received at the end of round 1 were analyzed using basic statistical techniques. The mean and median were determined as a measure of the central tendency of the responses for each project type and the corresponding phases of project development. The ranges and standard deviations were also determined as a measure of the variability in the responses.

The mean and median contingencies were determined for each category as shown in Tables 28 to 30. The mean contingency values were quite high due to the presence of some particularly high individual assessments of contingency. Some participants provided contingency values as high as 300, 400 and 450 percent in the high end of the contingency range in the planning phase of project development for complex projects in particular. The high values were attributed to the need for sufficient contingency to cover project unknowns that early in project development. The participants that provided high values of contingency indicated that they usually determine associated contingencies by performing risk assessments on the projects. On the other hand, the median values determined for each category of projects were lower than the means within similar categories. Since the outcome of the study was dependent on the expert judgment of all the participants every input was highly relevant and high individual assessments could therefore not be disregarded.

**Table 28: Mean and Median Contingencies, Round 1  
(Non Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 1 MEAN			Round 1 MEDIAN		
				Low	MLE	High	Low	MLE	High
Non Complex	Planning	10 to 20 yrs from letting	1 - 3%	22	38	60	15	25	30
	Programming/ Preliminary Design	5 to 10 yrs from letting	5 -15%	20	33	51	20	25	28
	Design 1	4 yrs or less from letting	15 - 40%	14	23	34	10	18	20
	Design 2	less than 4 yrs from letting	40 - 70%	9	15	22	8	12	15
	Design 3	less than 4 yrs from letting	70 - 100%	5	8	14	5	8	10

**Table 29: Mean and Median Contingencies, Round 1  
(Moderately Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 1 MEAN			Round 1 MEDIAN		
				Low	MLE	High	Low	MLE	High
Moderately Complex	Planning	10 to 20 yrs from letting	4 - 7%	31	56	87	25	30	50
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 25%	27	44	66	20	25	40
	Design 1	4 yrs or less from letting	25 - 35%	19	30	46	15	20	25
	Design 2	less than 4 yrs from letting	35 - 70%	13	21	30	10	15	20
	Design 3	less than 4 yrs from letting	70 - 100%	7	12	19	5	10	15



**Table 30: Mean and Median Contingencies, Round 1 (Most Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 1 MEAN			Round 1 MEDIAN		
				Low	MLE	High	Low	MLE	High
<b>Most Complex</b>	Planning	10 to 20 yrs from letting	7 - 15%	<b>44</b>	<b>74</b>	<b>118</b>	<b>30</b>	<b>45</b>	<b>50</b>
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 35%	<b>34</b>	<b>55</b>	<b>92</b>	<b>25</b>	<b>35</b>	<b>45</b>
	Design 1	4 yrs or less from letting	35 - 75%	<b>21</b>	<b>34</b>	<b>49</b>	<b>15</b>	<b>20</b>	<b>30</b>
	Design 2	less than 4 yrs from letting	75 - 100%	<b>12</b>	<b>21</b>	<b>33</b>	<b>7</b>	<b>10</b>	<b>20</b>

For non-complex projects, seven of the participants provided contingency values which were higher than the round 1 means, one participant provided contingency values right about the mean while the other fifteen provided values which were lower than or close to the mean. For the moderately complex projects only seven participants provided values that were consistently higher than the round 1 means for all the phases of project development, one provided values close to the mean and the other fifteen were well lower than the mean. In this category of projects seventeen participants provide values that were lower than the mean with a few of them close to the mean. The other six were way above the means (Table 31).

For the non complex projects only seven participants provided values that were consistently lower than the median, the other sixteen were higher than the median for all phases of project development. The moderately complex projects category had six participants that provided values lower than the median values, the other seventeen participants provided higher values than the median. Fourteen participants provided contingency values lower than the median for the most complex projects category (Table 31).

It was observed that most of the participants maintained their relative assessment positions relative to the round 1 means. For instance a participant who provided contingency values higher than the mean for non complex projects was often the same one that provided higher values than the mean for most complex projects. A similar pattern was observed in the participants' responses relative to the median. Table 31 shows a summary of the participants response pattern in the round 1 query relative to the round 1 group means and medians.

**Table 31: Participants' Response Patterns Relative to Round 1 Group Means/Medians**

Participants round 1 assessments relative to the following summary statistics	Non complex projects			Moderately complex projects			Most complex projects		
	Higher	About	Lower	Higher	About	Lower	Higher	About	Lower
<b>Round 1 Means</b>	7	1	15	7	1	15	6	0	17
<b>Round 1 Medians</b>	16	0	7	17	0	6	9	0	14
Numbers in the cells are the total number of participants whose round 1 assessments were in similar positions relative to the summary statistics									

It was observed that majority of the participants who had indicated higher contingency values for moderately complex projects were the same ones who indicated higher values in the most complex projects category. The ranges of the data were calculated as shown:

$$\text{Range} = \text{Highest observed value} - \text{Lowest observed value} \quad (5)$$

The data ranges were very high especially in the planning phase for non-complex projects; in one case the difference in the high and the low was up to 200 percentage points. Similar situations with even higher ranges were observed for the moderately

complex and most complex projects. The ranges were as high as 300 and 360 in the planning phase for moderately complex projects and most complex projects respectively (Table 32). For all three project types the lowest ranges were observed in the final design phase of project development. This could be attributed to the high degree of uncertainty in the planning phase and the variations in the methods used by SHAs to determine contingency. Three participants provided as much as 200 percent contingency in the high range of the planning phase for non-complex projects and explained that they determine appropriate contingencies based on the results of a comprehensive probabilistic risk analysis on projects. Specific comments provided the participants with high values indicated that the contingency values provided reflect the combined impact of cost, schedule and inflation risks since the project is still several years from construction letting. In addition one of the participants stated that from experience, design teams often do not account for schedule risk and inflation risk in their contingencies but instead may account for inflation on the base schedule as a line item.

For all three project types, based on the calculated ranges the highest variability occurred in the high end of the low, MLE and high contingency ranges for the planning phase of project development. For the non complex projects the range was 200 (the difference between the highest percent contingency, 200, and the lowest percent contingency of 0); for the moderately complex projects the range was 300 (the difference between the highest percent contingency, 300, and the lowest percent contingency of 0); for the most complex projects the range was 465 (the difference between the highest percent contingency, 500, and the lowest percent contingency of 35) (Table 32). This indicated that the variability in the data sets was very high in those phases of project development in the corresponding project type. The large amount of variability was attributed to the presence of outliers in the contingency values provided by the participants. Some SHAs use a predetermined percentage as contingency and do not associate the contingency directly with project risks. This method may understate or overstate the required contingency while other SHAs determine contingency based on the results of a

comprehensive risk analysis. The process of analyzing major project risks early in project development and determining potential impacts to project objectives provides estimators with an associated contingency value which gets added to the base estimate. The associated contingency is not 100 percent accurate because of the unpredictability of the future, but it is useful in preparing the project team for specific risks that may be encountered during the project and provides justification for the contingency included. General comments from a participant indicated that stake-holders may prefer deterministic estimates and added that range estimates are more effective in communicating uncertainty in the planning phase due to the low level of scope definition.

The lowest variability occurred in the low end of the low, MLE and high contingency ranges for the planning phase of project development for the three project types. For the non complex projects the range was 15 (the difference between the highest percent contingency in this category, 15, and the lowest percent contingency of 0); for the moderately complex projects the range was 20 (the difference between the highest percent contingency, 20, and the lowest percent contingency of 0); for the most complex projects the range was 50 (the difference between the highest percent contingency, 50, and the lowest percent contingency of 0) (Table 32).

**Table 32: Highest and Lowest Ranges, Round 1 Query**

Project Type/ Complexity	Non Complex (Minor) Projects						
Phase of Project Development		Planning			Design 3		
Level of Definition		1 - 3%			70 - 100%		
Years from letting		10 to 20			less than 4		
Contingency		Low	MLE	High	Low	MLE	High
Mean		23	41	67	5	9	15
Median		22	35	50	5	8	14
Standard deviation		15	29	61	4	6	11
Range	Highest	50	100	200	10	20	50
	Lowest	0	0	0	0	0	5
	Difference	50	100	200	10	20	45
Project Type/ Complexity	Moderately Complex Projects						
Phase of Project Development		Planning			Design 3		
Level of Definition		4 - 7%			70 - 100%		
Years from letting		10 to 20			less than 4		
Contingency		Low	MLE	High	Low	MLE	High
Mean		32	59	93	8	13	21
Median		30	50	75	7	10	19
Standard deviation		24	54	95	6	8	14
Range	Highest	75	200	300	20	30	60
	Lowest	0	0	0	0	5	5
	Difference	75	200	300	20	25	55
Project Type/ Complexity	Most Complex (Major) Projects						
Phase of Project Development		Planning			Design 2		
Level of Definition		7 - 15%			75 - 100%		
Years from letting		10 to 20			less than 4		
Contingency		Low	MLE	High	Low	MLE	High
Mean		47	77	127	12	22	35
Median		40	60	100	10	20	30
Standard deviation		29	65	134	12	22	36
Range	Highest	100	200	400	40	80	160
	Lowest	5	30	40	5	5	5
	Difference	95	170	360	35	75	155

Highest Range	
Lowest Range	

The standard deviations were calculated for each project category and like the ranges they were higher in the planning phase for the three project types and reduced gradually across the other phases of project development and were lowest in the final stages of design. This is due to improved scope definition and less uncertainty in the estimate later in project development. The highest standard deviations were observed in the planning phase for the most complex projects category (Table 32) and indicated a higher level of variability and a correspondingly lower level of consensus or agreement in the values provided by the participants. Table 33 provides the full details about the standard deviations, ranges, means and medians across the phases of project development in the three categories. On the contrary the lowest standard deviations observed in the final design phase for the non-complex projects indicated a much higher level of agreement in the values of contingency provided by the participants. The high standard deviation for most complex projects reflects variability due to the intricate nature of such projects and the differences in methods of addressing the uncertainties involved in such projects. It may also be an indication of different levels of conservatism of estimators in preparation of project estimates. Most complex projects very often have more unique risks and major design considerations than moderately or non complex projects. Often the use of predetermined percentages, since they are not directly tied to risks, may not take into account the unique risks due to the complexity of major projects. Some less conservative estimators may feel comfortable with planning estimates only if they include a high percentage contingency (determined from the result of a risk analysis) in cost estimates to cover the unknown major risks that may exist on most complex projects. Other estimators, from experience, may feel more comfortable with less contingency in planning.

Typically, in the non complex and moderately complex projects categories the risks are not as major and do not require contingencies as high. In some cases for non complex projects a risk checklist is sufficient by way of risk analysis for estimators to be able to determine what contingency may be adequate to include in the base estimate.

The range and the standard deviation both indicate a high level of variability in the data. The variability may also be very pronounced due to the size of the panel of experts. For smaller panels, the range is not as robust a measure of variability as the standard deviation but is extremely useful in identifying extremes in the contingency values provided by participants. Based on the results of round 1, it could be argued that the median values seemed more realistic than the mean values and may have been used as the main feedback to the participants. However, in this study the mean was used as the main feedback. Participants provided the contingency values based on their expert judgment and applications on projects; they also provided comments about what is typically included in their stated contingencies and the techniques used by their organizations to determine the contingencies.

**Table 33: Round 1 Group Summary Statistics**

Non Complex Projects	Phase of Project Development		Planning			Prog./ Preliminary Design			Design 1			Design 2			Design 3		
	Level of Definition		1 - 3%			5 - 15%			15 - 40%			40 - 70%			70 - 100%		
	Years from letting		10 to 20			5 to 10			4 or less			less than 4			less than 4		
	Contingency		Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
	Mean		22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
	Median		15	25	30	20	25	28	10	18	20	8	12	15	5	8	10
	Standard deviation		15	29	61	13	25	51	10	15	32	7	10	18	4	6	11
	Range	Highest	50	100	200	50	100	200	40	60	120	25	40	80	15	20	50
		Lowest	0	0	0	0	10	12	0	8	10	0	5	6	0	0	4
		Difference	50	100	200	50	90	188	40	52	110	25	35	74	15	20	46
Moderately Complex Projects	Phase of Project Development		Planning			Prog./ Preliminary Design			Design 1			Design 2			Design 3		
	Level of Definition		4 - 7%			15 - 25%			25 - 35%			35 - 70%			70 - 100%		
	Years from letting		10 to 20			5 to 10			4 or less			less than 4			less than 4		
	Contingency		Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
	Mean		31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
	Median		25	30	50	20	25	40	15	20	25	10	15	20	5	10	15
	Standard deviation		24	54	95	20	41	66	12	22	46	10	15	27	6	8	14
	Range	Highest	100	200	300	100	150	240	50	90	180	40	60	120	20	30	60
		Lowest	0	0	0	0	10	20	0	10	12	0	5	8	0	2	5
		Difference	100	200	300	100	140	220	50	80	168	40	55	112	20	28	55
Most Complex Projects	Phase of Project Development		Planning			Prog./ Preliminary Design			Design 1			Design 2					
	Level of Definition		7 - 15%			15 - 35%			35 - 75%			75 - 100%					
	Years from letting		10 to 20			5 to 10			less than 4			less than 4					
	Contingency		Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High			
	Mean		44	74	118	34	55	92	21	34	49	12	21	33			
	Median		30	45	50	25	35	45	15	20	30	7	10	20			
	Standard deviation		29	65	134	26	50	116	18	31	52	12	22	36			
	Range	Highest	100	250	500	100	200	500	75	125	240	50	80	160			
		Lowest	0	20	35	0	15	25	0	10	15	0	5	5			
		Difference	100	230	465	100	185	475	75	115	225	50	75	155			



Participants made some general comments about the levels of comfort at different phases in the contingency estimating process. The majority of comments indicated that most of those participants are very concern about unknown risks and future costs at the planning phase of project development irrespective of project complexity, and therefore tend to apply higher contingencies in the planning phase of projects. A few participants expressed a preference for risk analysis in the planning phase to be able to determine a contingency amount which is directly related to the identified project risks. In the design phase the participants agree that due to incomplete project definition early in the design phase there is still a large amount of uncertainty in the estimate especially for most complex projects. One participant indicted that even at 35 to 70% design completion, less than four years to letting, environmental documentation is still underway, and project definition is being refined. As a result most complex projects often have a higher likelihood of legal challenges, funding delays, and adverse market conditions which can cause project delays, increased costs or a combination of both. Participants' actual comments are included in Table D-1 – Respondents' Comments, Round 1.

Approximately 17% of the participants provided contingency values that were significantly higher than the other participants' values and also provided comments about their usage of such high values. A past study on the Delphi approach (Hallowell and Gambatese 2009) suggests the use of the median as feedback to the participants to eliminate the effects of bias in the results. However, using the median as the main feedback at this point may have reduced the clarity of the effects of the input from all 23 participants on the round 1 results. In this study the mean was used as the main feedback to the participants so that they could see the overall effects of their assessments on the entire results; however, they were also provided with other major summary statistics including the median, range, standard deviation to give them a broad picture of the total results. Comments provided in round 1 by participants were included as part of the feedback in round 2 so that all participants would have information as to what was included in the contingencies stated by other participants. All participants were

requested to review the summary statistics to be able to make informed decisions while reviewing their contingencies in round 2.

### Round 2 Query Results

Tables 34 to 36 show the round 2 mean and median contingencies.

**Table 34: Mean and Median Contingencies, Round 2 (Non Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 2 MEAN			Round 2 MEDIAN		
				Low	MLE	High	Low	MLE	High
Non Complex	Planning	10 to 20 yrs from letting	1 - 3%	23	41	67	22	35	50
	Programming/ Preliminary Design	5 to 10 yrs from letting	5 - 15%	21	34	54	20	30	40
	Design 1	4 yrs or less from letting	15 - 40%	16	25	38	14	20	30
	Design 2	less than 4 yrs from letting	40 - 70%	10	17	25	9	15	20
	Design 3	less than 4 yrs from letting	70 - 100%	5	9	15	5	8	14

**Table 35: Mean and Median Contingencies, Round 2  
(Moderately Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 2 MEAN			Round 2 MEDIAN		
				Low	MLE	High	Low	MLE	High
Moderately Complex	Planning	10 to 20 yrs from letting	4 - 7%	32	59	93	30	50	75
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 25%	26	43	69	25	40	60
	Design 1	4 yrs or less from letting	25 - 35%	20	32	51	20	30	40
	Design 2	less than 4 yrs from letting	35 - 70%	14	22	33	13	20	30
	Design 3	less than 4 yrs from letting	70 - 100%	8	13	21	7	10	19

**Table 36: Mean and Median Contingencies, Round 2 (Most Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	Round 2 MEAN			Round 2 MEDIAN		
				Low	MLE	High	Low	MLE	High
<b>Most Complex</b>	Planning	10 to 20 yrs from letting	7 - 15%	<b>47</b>	<b>77</b>	<b>127</b>	<b>40</b>	<b>60</b>	<b>100</b>
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 35%	<b>36</b>	<b>60</b>	<b>92</b>	<b>34</b>	<b>50</b>	<b>75</b>
	Design 1	4 yrs or less from letting	35 - 75%	<b>21</b>	<b>33</b>	<b>51</b>	<b>20</b>	<b>28</b>	<b>40</b>
	Design 2	less than 4 yrs from letting	75 - 100%	<b>12</b>	<b>22</b>	<b>35</b>	<b>10</b>	<b>20</b>	<b>30</b>

The mean values changed slightly at the end of the round 2 query. The highest change was an increase of 10 percentage points which occurred at the high extreme of the contingency values in the planning phase of project development for the most complex projects. In five instances across the phases of project development for the different project types the round 2 mean remained the same as the round 1 mean.

The median values at the end of round 2 were substantially higher than the round 1 median values. The maximum increase was 50 percentage points in the high extreme of the contingency values in the planning phase for most complex projects; in at least four instances across the phases of project development for the different project types the median remained the same. The lower bounds of the median contingency ranges became higher and were only slightly less than the corresponding lower bounds for the mean contingency ranges.

The standard deviation decreased only minimally across the phases of project development for the three project types. Majority of the decreases were between one and four points; however the most substantial decrease of 38 in the standard deviation occurred in the high extreme of the contingency values in the programming phase for the most complex projects category (where the largest increase in the mean and median

values occurred). Overall the variability decreased substantially from round 1 because majority of the participants lowered their initial assessment. Table 37 shows a comparison between round 1 and round 2 means, medians and standard deviations. For full comparisons including the round 1 and round 2 ranges, see Appendix G.

In Table 37, the negative sign indicates a decrease in the statistic from the previous round. Zero indicates no change in the statistic from the previous round.

The majority of the participants revised their round 1 assessment. Changes in contingency between one and ten percentage points in any one category were considered to be minor changes while changes between thirty and 100 percentage points were considered to be major changes. After comparing individual responses from round 1 and round 2, it was observed that most of the participants that revised their initial assessments and made minor changes to the ranges of contingency in at least one phase of project development within any of the project categories. To be considered a major change, participants had to make changes of 30 to 100 percentage points to the most likely estimate of contingency in at least four phases of project development in all of the project categories.

For non-complex projects, 11 participants had contingency values which were either much higher than or very close to the round 1 means, implying the four participants had made major changes to their round 1 assessments, while the other 12 had ranges which were lower than the mean. For the moderately complex projects 11 participants provided values that were consistently higher than the round 1 means for all the phases of project development which meant that four participants had made major changes to their round 1 assessments, while for the most complex projects category 11 participants provided ranges that were consistently higher than the round 1 means; the other 12 participants had ranges which were lower than or about the mean (summary of participants response patterns is shown in Table 38). Eight participants maintained their initial responses across the three project types/complexities.

**Table 37: Differences between Round 1 and Round 2 Means, Medians and Standard Deviations**

PROJECT TYPE	STATISTIC	ROUND	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Non Complex	Mean	Round 1	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
		Round 2	23	41	67	21	34	54	16	25	38	10	17	25	5	9	15
		Difference	1	3	7	1	1	3	2	2	4	1	2	3	0	1	1
Moderately Complex	Mean	Round 1	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
		Round 2	32	59	93	26	43	69	20	32	51	14	22	33	8	13	21
		Difference	1	3	6	-1	-1	3	1	2	5	1	1	3	1	1	2
Most Complex	Mean	Round 1	44	74	118	34	55	92	21	34	49	12	21	33			
		Round 2	47	77	127	36	60	92	21	33	51	12	22	35			
		Difference	3	3	9	2	5	0	0	-1	2	0	0	2			
Non Complex	Median	Round 1	15	25	30	20	25	28	10	18	20	8	12	15	5	8	10
		Round 2	22	35	50	20	30	40	14	20	30	9	15	20	5	8	14
		Difference	7	10	20	0	5	12	4	2	10	1	3	5	0	0	4
Moderately Complex	Median	Round 1	25	30	50	20	25	40	15	20	25	10	15	20	5	10	15
		Round 2	30	50	75	25	40	60	20	30	40	13	20	30	7	10	19
		Difference	5	20	25	5	15	20	5	10	15	3	5	10	2	0	4
Most Complex	Median	Round 1	30	45	50	25	35	45	15	20	30	7	10	20			
		Round 2	40	60	100	34	50	75	20	28	40	10	20	30			
		Difference	10	15	50	9	15	30	5	8	10	3	10	10			
Non Complex	Standard deviation	Round 1	15	29	61	13	25	51	10	15	32	7	10	18	4	6	11
		Round 2	12	26	56	10	22	48	9	13	29	6	9	17	3	5	11
		Difference	-3	-3	-5	-3	-3	-3	-1	-2	-3	-1	-1	-2	-1	-1	0
Moderately Complex	Standard deviation	Round 1	24	54	95	20	41	66	12	22	46	10	15	27	6	8	14
		Round 2	18	47	87	11	25	55	9	18	42	8	12	23	5	7	13
		Difference	-6	-7	-8	-9	-16	-11	-3	-4	-4	-2	-3	-4	-1	-1	-1
Most Complex	Standard deviation	Round 1	29	65	134	26	50	116	18	31	52	12	22	36			
		Round 2	26	53	109	21	43	78	12	22	45	9	16	31			
		Difference	-3	-12	-25	-5	-7	-38	-6	-9	-7	-3	-6	-5			

**Table 38: Participants' Response Patterns in Round 2 Relative to Round 1 Group Means/Medians**

Participants round 2 assessments relative to the round 1 means	Non complex projects			Moderately complex projects			Most complex projects		
	Higher	About	Lower	Higher	About	Lower	Higher	About	Lower
Round 1 Assessment	7	1	15	7	1	15	6	0	17
Round 2 Assessment	11	0	12	11	0	12	11	0	12
Revisions in round 2	+4	-1	-3	+4	-1	-3	+5	0	-5
Total Revisions	15			15			17		
Revisions in round 2 are the numbers of participants who made major changes to their round 1 assessment. The + sign before a number indicates ‘more participants’ in that category while the negative sign indicates ‘fewer’.									
Total revisions are the total number of participants who made changes to their round 1 assessments (minor and major changes)									

In round 2 participants were asked to provide comments supporting any revisions to their initial assessments of contingency in round 1. The comments were meant to provide the researcher with an understanding of what may be included in the contingencies and why the changes were necessary in the light of new information from the previous round.

Some participants who revised their initial assessment upwards in the planning and programming phases did so after reconsidering major project risks unidentified at that phase of project development. Such risks include environmental issues, utility relocation issues, major structural issues and stakeholder issues especially for most complex projects. A few participants indicated that unpredictable external market factors have the potential to increase project costs if contingency is not sufficient and therefore either increased their contingency values or maintained their initial assessment from round 1. Participants' round 2 comments are included in Table H-1 (Participants' Comments, Round 2).

### Round 3 Query Results

The round 3 means and medians are shown in Tables 39 to 41. In round 3, majority of the participants maintained their previous responses while a few made changes to their previous assessments in round 2. Most of the changes made were slight revisions either upward or downward except for a few participants that made substantial decreases in round 3 from their round 2 assessments. There were no consistent increases or decreases in the mean and median values from their round 2 assessments.

The mean values changed slightly at the end of the round 3 query. The highest change was an increase of three percentage points which occurred in three instances across the phases of project development for the most complex projects. The other changes in the mean of zero, one and two percentage points occurred mostly in the moderately complex projects. For the non-complex projects the mean remained the same as the round 2 means, increased by one percentage point or decreased by one percentage point across the project development phases. The majority of the median values at the end of round 3 remained the same. The maximum increase in the median was five percentage points occurring in the high ranges of the programming phases of non-complex and most complex projects respectively.

**Table 39: Mean and Median Contingencies, Round 3 (Non Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	MEAN			MEDIAN		
				Low	MLE	High	Low	MLE	High
Non Complex	Planning	10 to 20 yrs from letting	1 - 3%	24	41	68	23	35	55
	Programming/ Preliminary Design	5 to 10 yrs from letting	5 -15%	21	34	56	20	30	45
	Design 1	4 yrs or less from letting	15 - 40%	16	25	38	15	20	30
	Design 2	less than 4 yrs from letting	40 - 70%	11	17	25	10	15	22
	Design 3	less than 4 yrs from letting	70 - 100%	5	9	14	5	9	15

**Table 40: Mean and Median Contingencies, Round 3  
(Moderately Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	MEAN			MEDIAN		
				Low	MLE	High	Low	MLE	High
Moderately Complex	Planning	10 to 20 yrs from letting	4 - 7%	33	59	92	30	50	75
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 25%	27	43	68	25	40	60
	Design 1	4 yrs or less from letting	25 - 35%	21	31	50	20	30	40
	Design 2	less than 4 yrs from letting	35 - 70%	15	22	32	14	20	30
	Design 3	less than 4 yrs from letting	70 - 100%	8	13	20	7	10	20

**Table 41: Mean and Median Contingencies, Round 3 (Most Complex Projects)**

Project Type	Phase of Project Development	Phase Description	Level of Definition	MEAN			MEDIAN		
				Low	MLE	High	Low	MLE	High
Most Complex	Planning	10 to 20 yrs from letting	7 - 15%	47	75	125	40	60	100
	Programming/ Preliminary Design	5 to 10 yrs from letting	15 - 35%	36	59	89	35	50	80
	Design 1	4 yrs or less from letting	35 - 75%	20	31	48	20	30	49
	Design 2	less than 4 yrs from letting	75 - 100%	12	21	32	10	20	30

Despite the fact that only a few participants actually revised their round 2 assessments, the variability decreased significantly as seen from the ranges (Table 42) and the standard deviations (Table 43) for the different project types. The majority of the revisions made by participants were between one and ten points and a few closer to 20 percentage points, the changes were made only in a few phases of project development in some project categories. Further analysis of the results indicated that the revisions



made in round 3 by two participants with values much higher than the round 2 means were the main drivers of the substantial decrease in the variability. Some of the decreases in contingency values made by those participants were as high as 120 and 140 percentage points in some categories. One participant revised a contingency value of 400 in the high range of planning for most complex projects downward by 140 from the round 2 assessment. A few other decreases by 120, 120 and 100 were made by the same participant in the high ranges of the programming, design 1 and design 2 phases of project development for most complex projects. However, changes made to the most likely estimate of contingency by the participant were between 40 and 60 percentage points, not as substantial as the changes made to the high end of the contingency range. The participant explained that there is a large amount of uncertainty in most complex projects and the uncertainty in the estimates does not reduce as rapidly for most complex projects as it does for moderately complex and non complex projects. For this reason the changes in made by the participant to the most likely estimate of contingency in round 3 did not exceed 60 percentage points to account for the uncertainty. However, with a thorough risk analysis process the high ends of the contingency ranges for most complex projects can be tightened substantially as shown by the drastic reductions of 120 to 140 points in round 3. The participant explained that when design is close to 100 percent, a contingency of 10 to 20 percent may be more appropriate although some agencies require an additional four to five percent contingency to cover change orders after contract award.

The standard deviation decreased by a maximum of 13 percentage points occurring twice in the planning and programming phases for the most complex projects. Other decreases in standard deviations were between one and eight percentage points for the moderately complex and non-complex projects.

**Table 42: Data Ranges (Rounds 1, 2, and 3)**

ROUND	PROJECT TYPE	STATISTIC	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Round 1	Non Complex	Range	50	100	200	50	90	188	40	52	110	25	35	74	15	20	46
		High end of range	50	100	200	50	100	200	40	60	120	25	40	80	15	20	50
		Low end of range	0	0	0	0	10	12	0	8	10	0	5	6	0	0	4
Round 2	Non Complex	Range	50	100	200	40	100	200	40	50	105	20	35	70	10	20	45
		High end of range	50	100	200	40	100	200	40	60	120	20	40	80	10	20	50
		Low end of range	0	0	0	0	0	0	0	10	15	0	5	10	0	0	5
Round 3	Non Complex	Range	50	100	200	40	100	200	35	50	85	15	27	50	10	15	25
		High end of range	50	100	200	40	100	200	40	60	100	20	35	60	10	20	30
		Low end of range	0	0	0	0	0	0	5	10	15	5	8	10	0	5	5
Round 1	Moderately Complex	Range	100	200	300	100	140	220	50	80	168	40	55	112	20	28	55
		High end of range	100	200	300	100	150	240	50	90	180	40	60	120	20	30	60
		Low end of range	0	0	0	0	10	20	0	10	12	0	5	8	0	2	5
Round 2	Moderately Complex	Range	75	200	300	60	100	215	45	75	160	40	50	105	20	25	55
		High end of range	75	200	300	60	120	240	45	90	180	40	60	120	20	30	60
		Low end of range	0	0	0	0	20	25	0	15	20	0	10	15	0	5	5
Round 3	Moderately Complex	Range	80	200	300	52	80	175	44	60	130	36	40	65	18	25	45
		High end of range	80	200	300	60	100	200	50	75	150	40	50	80	20	30	50
		Low end of range	0	0	0	8	20	25	6	15	20	4	10	15	2	5	5
Round 1	Most Complex	Range	100	230	465	100	185	475	75	115	225	50	75	155			
		High end of range	100	250	500	100	200	500	75	125	240	50	80	160			
		Low end of range	0	20	35	0	15	25	0	10	15	0	5	5			
Round 2	Most Complex	Range	95	170	360	95	175	295	55	105	225	35	75	155			
		High end of range	100	200	400	100	200	320	60	120	240	40	80	160			
		Low end of range	5	30	40	5	25	25	5	15	15	5	5	5			
Round 3	Most Complex	Range	80	170	360	85	175	275	30	45	105	25	35	65			
		High end of range	100	200	400	100	200	300	40	60	120	30	40	70			
		Low end of range	20	30	40	15	25	25	10	15	15	5	5	5			

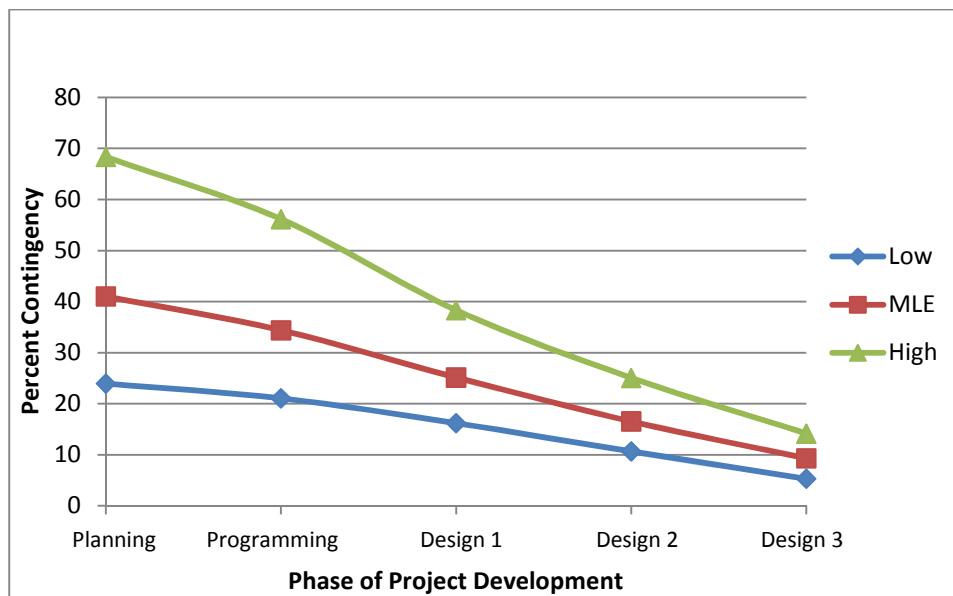
**Table 43: Standard Deviations (Rounds 1, 2, and 3)**

ROUND	PROJECT TYPE	STATISTIC	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Round 1	Non Complex	Standard deviation	15	29	61	13	25	51	10	15	32	7	10	18	4	6	11
Round 2	Non Complex	Standard deviation	12	26	56	10	22	48	9	13	29	6	9	17	3	5	11
Round 3	Non Complex	Standard deviation	11	26	56	10	22	48	8	13	26	5	7	14	3	4	6
Round 1	Moderately Complex	Standard deviation	24	54	95	20	41	66	12	22	46	10	15	27	6	8	14
Round 2	Moderately Complex	Standard deviation	18	47	87	11	25	55	9	18	42	8	12	23	5	7	13
Round 3	Moderately Complex	Standard deviation	17	44	80	10	22	47	9	16	34	9	10	16	4	6	9
Round 1	Most Complex	Standard deviation	29	65	134	26	50	116	18	31	52	12	22	36			
Round 2	Most Complex	Standard deviation	26	53	109	21	43	78	12	22	45	9	16	31			
Round 3	Most Complex	Standard deviation	23	49	96	18	39	65	9	12	24	6	10	16			

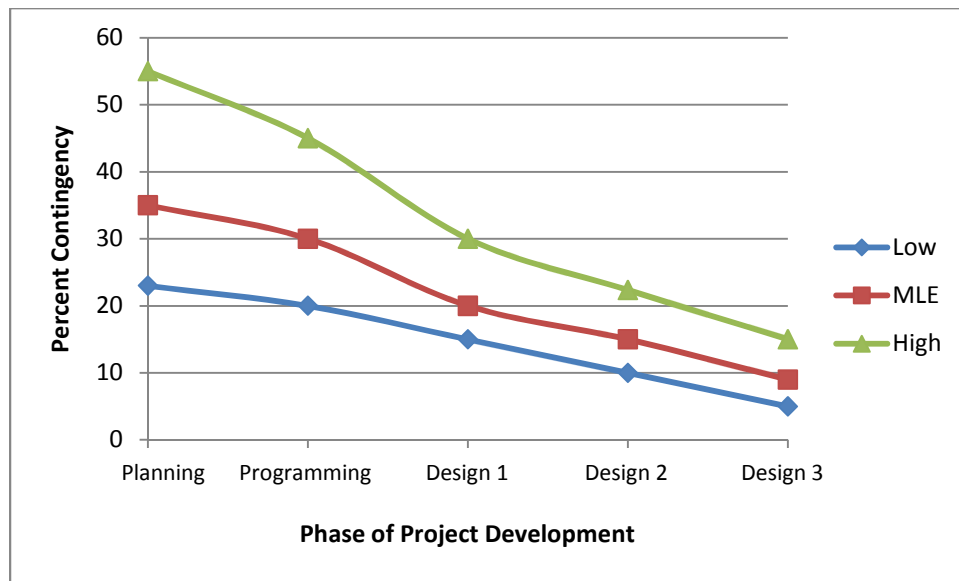
The decrease in variability was also very highly noticeable in the ranges. The highest decrease in the range was 120 percentage points in high end of the contingency ranges in the design 1 phase of project development for most complex projects. The next highest decrease in the range was 40 percentage points in the design 2 phase of moderately complex projects. The other decreases in the range were less than 20 percentage points.

### Presentation of Sliding Scale Contingencies

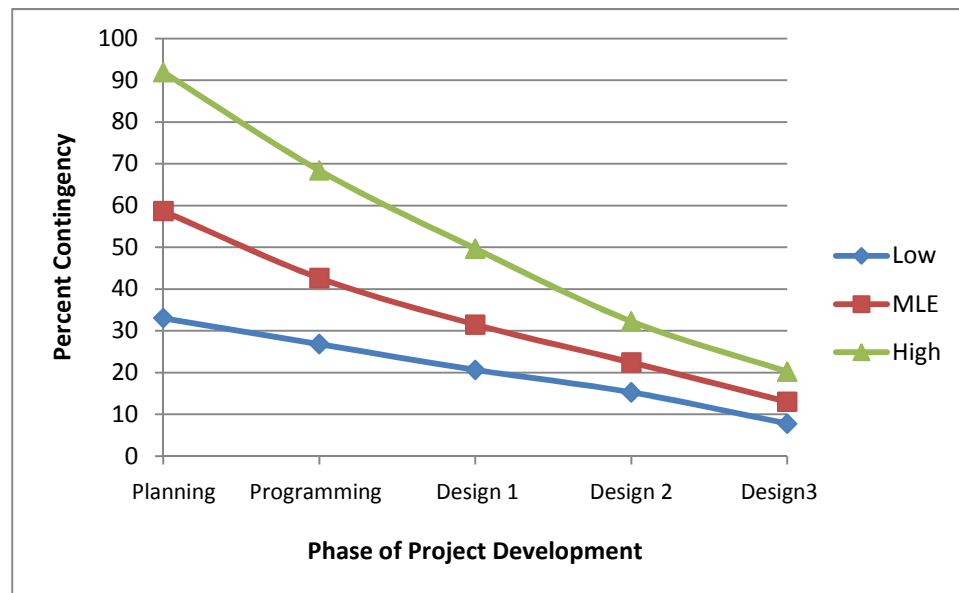
The full details of all the parameters used by the participants in assessing the contingencies are provided in the matrix described previously in Table 17. The sliding scale contingencies are shown in Figures 15 through 20 using the means and the median contingencies from the participants' assessments.



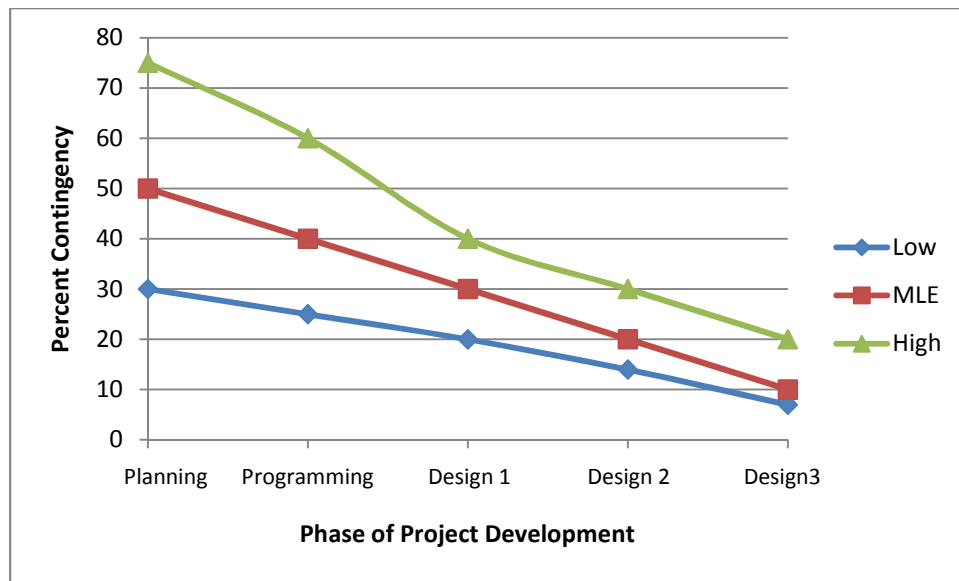
**Figure 15: Mean Sliding Scale Contingency (Non-Complex Projects)**



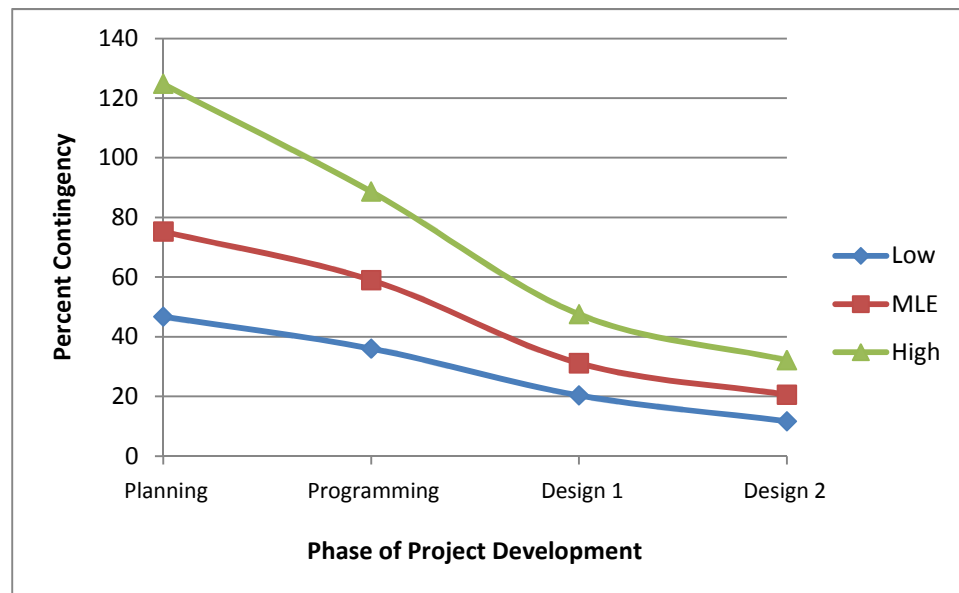
**Figure 16: Median Sliding Scale Contingency (Non-Complex Projects)**



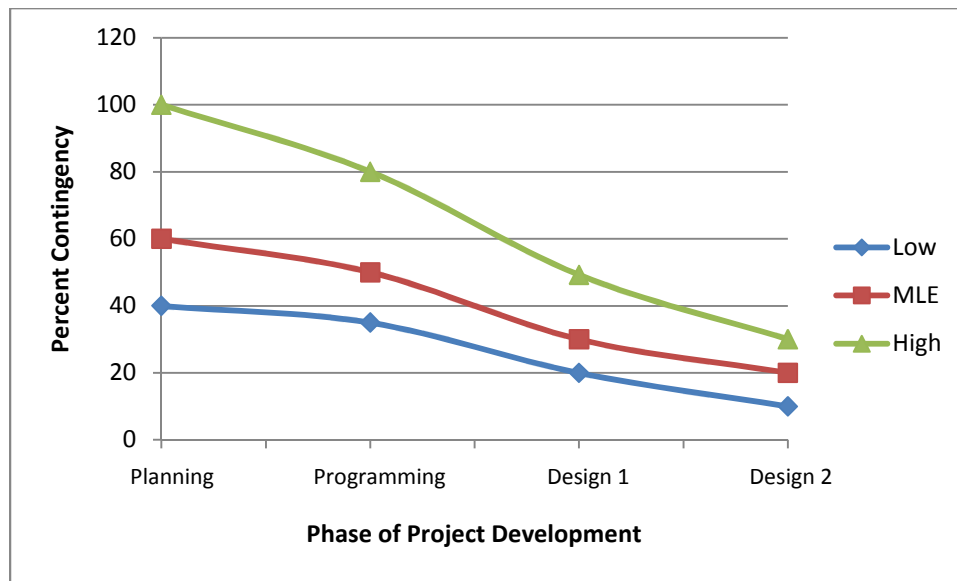
**Figure 17: Mean Sliding Scale Contingency (Moderately Complex Projects)**



**Figure 18: Median Sliding Scale Contingency (Moderately Complex Projects)**



**Figure 19: Mean Sliding Scale Contingency (Most Complex Projects)**



**Figure 20: Median Sliding Scale Contingency (Most Complex Projects)**

The sliding scale contingencies (Figures 15 through 20) indicate that the contingency percent at the design 3 phase is not zero. This is partly due to the level of definition used to describe the design phases in this study (Table 16). For instance, the level of definition in design 3 for moderately complex projects is 70 – 100%. The estimates of contingency (Low, MLE, and High) shown likely represent a level of definition around 85%. The contingencies in the final design phases for the three project types reflect a small amount of uncertainty in the final design and contingency for construction administration.

## Summary

The response rate remained at 100% through the three rounds of the survey. Obtaining a high response rate was very important to ensure consistency in the overall results. At the end of round 1 the mean contingencies were very high due to the presence of some high contingency ranges in the data received from the participants. The medians were also high but not as high as the mean. The range and standard deviation showed that the variability in the results was high and reduced in round 2 and even further reduced in round 3. The most significant changes to the participants' assessments of contingency were made in round 2 (see Appendix J for a comparison of the full summary statistics for rounds 1, 2 and 3 including mean and median contingencies). In rounds 1 and 2 some participants provided comments that provided justification for the contingency values indicated. Some of the comments included their assumptions, clarifications, factors that affect contingencies and what is included in the contingency ranges.

The mean was used as the major feedback to the participants at the end of each round because at the end of round 1 it was necessary for participants to see the impact of their assessments on the group response for the preceding round and the mean showed this most clearly. Participants were also provided all the other summary statistics from the rounds – the median, the standard deviation and the range. This was done to give all participants a full picture of the results of the rounds showing the variability in the results. A summary of all the comments provided by participants was also included as part of the feedback in subsequent rounds. The comments were included so that participants could understand what was included in the contingency ranges and could therefore make informed decisions if they decided to review their previous assessments.

At the end of the round 3 query a few of the contingency ranges were still substantially higher than the majority especially for the most complex projects. The high ranges could introduce bias in the results due to a disproportionate slant towards higher individual values in the results. For this reason, the median was reviewed and compared with the



means. The median values were lower than the means, in one instance (planning phase for most complex projects) the median was up to 25 percentage points lower than means from the same round. In other cases the differences were not as substantial. However, to minimize any bias in the results, the median was used to convey the final results. For the purposes of this study, the sliding scales will be shown using both the mean and the median. Estimators are encouraged to use the median sliding scales.

Some of the comments provided by the participants indicated that the following were included in their contingencies:

- Costs for cost overruns and change orders during construction.
- 5-10% for Minor Items and 5% for Supplemental Work that cannot be identified at the time of the estimate except for Plans, Specifications, & Estimate. These items of work must be quantified in the final estimate.
- Any amount for commodity price risks due to length of time prior to letting.

Some participants indicated that the stated contingencies do not include the following:

- Allowances for items that are known to be required as part of the base project, but that are not yet quantified in the cost estimate.
- Allowances for cost escalation.
- Funds available for cost adjustments driven by predetermined market factors and incentives.

The contingency bands on the sliding scales contrast sharply with the Ohio sliding scale shown in Figure 1 and the contingency values are higher for all the three project complexities. The Ohio scale has a maximum range of 25 to 35 percent at zero percent design completion in the planning phase and the ranges decrease linearly until they zero percent contingency at 100 percent design completion. The sliding scale developed for non complex projects has a maximum range of 23 to 55 percent contingency with a most likely value of 35 percent. However, the contingency in design 3 when the level of

definition is between 70 to 100 percent, the contingency band does not reach zero percent. This is because of the use of a range of definition, the actual definition at that stage of design is probably somewhere around 85 to 90 percent. Furthermore, from comments provided by participants some SHAs are required to include about four to five percent contingency in the engineers estimate at 100 percent design completion to cover change orders after contract award.

## **CHAPTER VI**

### **APPLICATIONS OF THE SLIDING SCALE CONTINGENCIES**

#### **Applications of the Sliding Scale Contingencies**

State Highway Agencies may use this method to estimate contingency on their projects. It takes into account the effect of complexity which is one major factor that affects contingency. The cost estimation process typically involves the preparation of the estimate basis from which the base estimate is determined. Some estimators include contingencies in the line items to hedge the effects of inflation or other factors that can cause variability in cost estimates. The application of this method of setting contingency is most successful when estimators ensure that all line item contingencies or other contingencies have been separated from the base estimate of the project. The application of this method comprises six basic steps:

- Step 1: Estimators must ensure that no line item contingencies have been included in their base estimates. All contingencies and conservative biases must be removed from the base estimate; if they are not removed from the base estimate, the use of this method may lead to excessively high project estimates. In this study contingency assessments were made by participants with an understanding that the base estimate will not include any line item contingencies or other biases prior to applying the sliding scale contingencies.
- Step 2: Classify the project as Non-Complex (Minor), Moderately Complex or Most Complex (Major) using complexity definitions described in Table 11 and shown fully in Tables A-1, A-2, and A-3. Proper classification is required to ensure that the most appropriate sliding scale is used to estimate the contingency.
- Step 3: Determine the current phase of project development using information provided in Table 17. The time of estimate

preparation in the project life cycle is a very important factor because as a project moves further along in the project development the level of scope definition is increased. This, in turn, reduces the amount of uncertainty in the project. Some risks or previous unknowns become known as scope definition increases and the contingency required starts to decrease.

Step 4: Perform a qualitative risk identification or assessment to determine potential risks that could impact the project objectives. Develop a project risk register which would be updated throughout the project lifecycle. It is advisable to establish potential mitigation plans for risks identified. The identification of risks provides estimators with an idea of the amount of uncertainty in the project at the time of estimate preparation and provides rationale for applying contingency to the project estimate using the sliding scales.

Step 5: Using the appropriate median sliding scale (Figures 16, 18 and 20) add the appropriate amount of contingency to the base estimate. This can be done in four ways:

- I. Estimators may use low and high estimates to create a range estimate.
- II. Estimators may use the most likely estimate for deterministic estimates.
- III. Estimators may choose a value between the upper and lower ends of the range as the likely estimate of contingency for deterministic estimates based on the projects risks. The estimator may need to identify unique project risks that could justify the use of a higher or lower contingency value than the most likely estimate (MLE).

IV. Estimators may choose two values between the upper and lower ends of the range to use to create a unique contingency range for projects. The estimator may need to identify risks that could justify the use of a tighter contingency range than the range created by using the upper and lower ends of the sliding scale contingencies.

Step 6: Repeat the process at each major phase of project development. This step is necessary because this method provides an added benefit of unstated retirement of contingency across the phases of project development. This step can be further justified by checking the retired risks (risks that did not occur or are no longer threats to the project). If many risks have been retired, for instance in the final design phase, it may provide justification for the use of a lower contingency in the final design estimate.

This method is a top-down method of estimating contingency since it does not tie contingency directly to project risks. Its use is based more on the level of experience of the estimator. However, estimators are encouraged to identify and assess project risks which may provide some justification especially to stakeholders for the amount of contingency included in the estimates. The risk list developed can also be used to track project risks and update risk status throughout the project. For large moderately complex or major projects which may have unique risks that require particular attention, it is recommended that a comprehensive risk assessment is performed to fully determine the potential impact of identified risks to the project. Unlike the sliding scales this is a bottom-up approach (Molenaar et al. 2008).

### **Risk Management Process**

NCHRP 8-60 risk management guidebook describes comprehensive risk management as a sequence of analysis and management activities focused on creating a project-specific

response to the inherent risks of developing a capital facility. Risk management is a continuous process throughout the lifecycle of a project and involves five basic steps (Molenaar et al. 2008) illustrated in Figure 21:



**Figure 21: Risk Management Process Framework (NCHRP 8-60)**

- **Risk identification:** This is the process of determining risks which may impact major project objectives. It is a process that should involve all stakeholders on a project and is performed by brainstorming and using tools such as checklists. A risk register should be developed containing all the identified risks on the project.
- **Risk assessment/analysis:** This is a qualitative or quantitative analysis of project risks to determine the likelihood of occurrence and the potential impact of each risk on the project objectives. A quantitative analysis can be performed using methods such as Monte Carlo simulation to determine the probability of different project outcomes. The outcome of a quantitative risk analysis can be used to determine associated contingencies to apply to project estimates.
- **Risk mitigation and planning:** This is the process of identifying potential response plans should any of the risks occur. It involves the analysis of different risk response options such as risk acceptance, risk avoidance, risk transference and risk mitigation.

- Risk allocation: This involves the assignment of individual risk responsibility to team members. Risks should be allocated to team members who may be best able to manage them.
- Risk monitoring and control: This is a process of keeping track of identified risks, reporting risk status, reviewing planned responses, and comparing with the initial risk management plan. This process assists cost estimators in tracking and retiring project contingency.

In the planning phase and early in the programming phase where the project definition is low introducing a high level of uncertainty in the project estimate, the author recommends the use of range estimates using the upper and lower ends of the sliding scale range or by choosing a tighter range within those limits based on project risks. The use of ranges is effective in communicating the amount of project uncertainty to stakeholders. These estimates should be refined as the project moves through programming and the level of definition increases. Estimates developed late in programming and in the later phases of project development are typically deterministic since they are used for project control and as such range estimating techniques may be less suitable.

For successful application of the sliding scales it is important to note that

- Using this method, the contingency ranges are not tied to project risks and for the method to be successful project risks should be identified and may be used as justification for the contingency values picked.
- To avoid excessively high estimates, all conservatism must be removed from the base estimate before applying the sliding scale contingency.

### **Benefits**

A major benefit of this study is that the sliding scale contingencies were developed by experts with rationale behind the assessment. Its use creates consistency in the process of

defining and estimating contingency on highway projects. SHAs often estimate contingency using different methods as outlined in Chapter II, but some of the methods either have no basis or lack consistent rationale behind their application. They are sometimes entirely subject to the judgment of the engineers or estimators preparing the estimate or are based on some standard percentages which do not take into account major factors that impact contingency. This method incorporates the effects of project complexity, level of definition, phase of project development, and methodology and purpose of estimation which are some major factors that affect the amount of contingency and reliability of a project cost estimate.

The sliding scales developed, due to the incorporation of complexity considerations and other major factors, may reflect higher amounts of contingencies than the Ohio design completion guidelines to cover estimate uncertainties for the different project types/complexities. Using this method, if an estimator identifies project risks and picks a suitable contingency value or range from the sliding scales, stakeholders should feel more comfortable with the estimate knowing that the method has taken into account the effects of complexity and identified risks for justification. The use of ranges in planning is strongly encouraged and further reinforces the communication of uncertainty to stakeholders. However, estimators are encouraged to perform a comprehensive analysis of unique project risks for larger moderately complex projects and most complex projects to determine associated contingencies directly tied to project risks. As a double check, estimators can compare the results of the comprehensive risk assessment to the sliding scale results for the same project complexities.

The results of this study depict a picture about how contingency ranges change over the lifecycle of a project. As seen in the sliding scales, contingency tends to decrease somewhat exponentially (rather than linearly) across the phases of project development whether non-complex, moderately complex or most complex projects. With this knowledge estimators would be better able to determine what values or ranges are most



appropriate when estimating contingency depending on the time of estimate preparation and project complexity. Estimators are encouraged to identify risks and use that as a justification for deterministic contingency values or ranges applied to project estimates. This risk list should be kept and updated throughout project development and used when estimated contingencies are revised.

Communication of estimates to stakeholders can be improved by using this method because it is a consistent method of estimating which can be justified by maintaining a project risk register. Stakeholders rely on project estimates to make vital funding decisions and to prioritize projects for execution in the state transportation improvement plans. One major problem most SHAs face is the problem of project cost escalation. While this method may not necessarily eliminate the problem of project cost escalation it can create some consistency and be used to communicate levels of uncertainty in the estimates to stakeholders for consideration during the decision making process.

The implied retirement of contingency is an important benefit of applying this method and this helps ease the contingency management process. As a project moves from planning through to design and then letting the contingency required will reduce because the level of scope definition is higher. A contingency of say 50% in the planning phase of a most complex project may decrease to 20% or 15% in the final phases of design before project letting since the scope has become better defined. In an ideal situation the base estimate should rise by the same percent decrease in contingency for an accurate estimate. In practice however, the base estimate will rise when the contingency decreases but probably not by the same amount. As much as possible contingency use should be tracked throughout a project and the risks should be resolved as a project moves through project development; this could improve an understanding of the process and improve the accuracy of estimates on similar future projects.

## **CHAPTER VII**

### **CONCLUSIONS AND RECOMMENDATIONS**

The sliding scale contingencies presented in this study were developed using judgment of experts in fields such as engineering, construction, project management, cost estimation and highway program management. Experimental methods were considered for use in achieving the study objectives but were not very applicable because they are more applicable where there is a predictable cause and effect relationship between variables with the effect remaining the same. Due to the unique nature of construction projects, it is very difficult to accurately predict the effect of any one factor on the amount of project cost contingency applied to a project. The Delphi method which is non-experimental was used because it lends its application to solving complex problems for which there is no empirical evidence.

Through a review of past research this study identified the following as some of the major factors that affect the amount of contingency provided in cost estimates for highway projects:

- Project type/complexity
- Phase of project development
- Level of project scope definition at time of estimate preparation
- Estimation type and methodology

The two most critical of these are the level of scope definition and the project complexity. This is because the uncertainty in a project decreases as more information becomes available about the project and this will likely enhance the accuracy of the base estimate and decrease the amount of contingency required. Furthermore, more complex projects will probably experience more unique and major project risks than non complex projects. This makes it necessary to include a larger percentage as contingency to account for the uncertainty.

The results of this study show that contingency decreases exponentially across the phases of highway project development. With this knowledge, estimators will be better able to select appropriate ranges or deterministic values of contingency to apply to projects.

## **Conclusions**

The assessment of contingency in this study was performed using the Delphi method, a method which relies heavily on the judgment of experts to solve a complex problem. There was no existing data to support the objectives of this study. The protocol development of this study provided different project complexity scenarios as a framework for the assessment of contingency by the panel of experts. This created consistency in the contingency definition and estimation for this study, and the sliding scales developed provide a consistent method which SHAs can use for assessment of contingency on their projects.

Contingency application varies from one SHA to another and across the phases of project development. SHAs use different methods such as predetermined contingencies, unique project contingencies and associated contingencies based on risk analyses. Some of the methods used lack consistent bases for their definition and use which impacts the accuracy of project estimates. The application of contingency also varies across the phases of project development. Typically early in planning contingency ranges are very high (in value) and very wide (low range to high range) to account for the high level of uncertainty due to low scope definition. In the final design phases the scope is almost fully defined, this reduces the amount of uncertainty in the estimate and the contingency required. Contingency ranges are also affected by project type. For instance using the median sliding scales, a contingency value within the range of 40% to 100% may be adequate for a most complex project in the planning phase whereas for a non-complex project also in the planning phase a range between 22% and 50% may be more suitable.

This is due to the higher level of uncertainty and the major risks due to design complexity.

The sliding scale contingency bands decrease non-linearly across the phases of project development. The shape of the curves suggest that early in the planning phase, high contingency ranges are required to account for the scope uncertainty. However, at the end of programming as the project moves into the design phases the required contingency decreases almost exponentially and then slopes gently down to the final design phase. This is most noticeable in the median sliding scale for the most complex projects category. This may be because early in planning a large amount of contingency is included to account for major project risks with potential impacts still undetermined. By the end of programming/preliminary design some of those major potential high impact risks may have been resolved and the scope definition improved implying the need for a much lower contingency than used in planning. In contrast, the Ohio design completion contingency guidelines suggest a linear decrease in the ranges of contingency across the phases of project development. It is likely that SHAs do not have supporting data to determine the way contingency changes across the phases of project development from planning to final design.

All summary statistics from previous rounds (means, medians, standard deviations, variance) were included in the feedback to participants at the start of the next round, though, the means were highlighted as the major feedback and the measure of consensus. However, it was observed that the mean ranges were very high and did not eliminate bias in the results due to the extremely high individual values of contingency. The median ranges on the other hand were lower, more consistent across the rounds of the Delphi study.

The final sliding scales were developed using the medians to minimize the effects of bias in the sliding scales. Six steps were recommended for the application of the sliding

scales across the phases of project development. The sliding scales can be used for range estimating in planning to enhance the communication of estimates to stakeholders and for deterministic estimating in the design phases of project development.

### **Recommendations**

The largest limitation of this study is the fact that the contingencies are not directly tied to risks. Estimators are encouraged to identify risks and update risk lists for all projects. Though for larger moderately complex and most complex projects a comprehensive analysis of unique project risks is recommended. Estimators can compare the results of the risk analysis to results using the sliding scale contingencies.

It is critical to note that for most effective application of the sliding scales it is important for estimators to ensure that all line item contingencies and other conservative biases and contingencies have been removed from the base estimate before using the sliding scales. This will prevent excessively high estimates.

This method creates consistency in applying contingency to highway projects, improves the communication of estimates to stakeholders, implies the retirement of contingency across the phases of project development and generally eases the contingency management process over the life cycle of a project. As contingency is retired, project teams are encouraged to identify risks that are retired as justification for the lower contingencies used. These include risks that did not materialize or are no longer threats to the project.

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**APPENDIX A**  
**PROTOCOL DEVELOPMENT**

**Table A-1: Non Complex Project Complexity Definitions  
(Anderson et al. 2007)**

<b>Non-Complex (MINOR) Projects</b>	
Roadway	<ul style="list-style-type: none"> <li>• Maintenance betterment projects</li> </ul>
	<ul style="list-style-type: none"> <li>• Overlay projects, simple widening without right-of-way (or very minimum right-of-way take) little or no utility coordination</li> </ul>
	<ul style="list-style-type: none"> <li>• Non-complex enhancement projects without new bridges (e.g. bike trails)</li> </ul>
Traffic Control	<ul style="list-style-type: none"> <li>• Single traffic control/management projects</li> </ul>
	<ul style="list-style-type: none"> <li>• Non-ITS but minor safety improvements</li> </ul>
Structures	<ul style="list-style-type: none"> <li>• Bridge resurfacing or repairs which do not require re-analysis of bridge capacity</li> </ul>
	<ul style="list-style-type: none"> <li>• Pipes, box culverts or minor culvert replacements where design can be picked directly from design manual or standards or using simple software where detailed interpretation is not necessary</li> </ul>
	<ul style="list-style-type: none"> <li>• Sign structures for which the design can be picked up directly from either the standards or using design computer software</li> </ul>
	<ul style="list-style-type: none"> <li>• Noise walls or retaining walls for which the design can be picked up directly from either the standards or using design computer software</li> </ul>
Right-of-Way	<ul style="list-style-type: none"> <li>• Involve minor right-of-way acquisitions with no displacements, maintain existing access control</li> </ul>
Utilities	<ul style="list-style-type: none"> <li>• Minimal, if any</li> </ul>
Environment	<ul style="list-style-type: none"> <li>• Categorical Exclusion (level 1A or 1B)</li> </ul>
	<ul style="list-style-type: none"> <li>• Minimum interaction with environmental and permitting agencies</li> </ul>
	<ul style="list-style-type: none"> <li>• Minor environmental impacts as appropriate have a Statewide Wetland Finding</li> </ul>
	<ul style="list-style-type: none"> <li>• Do not involve cultural resources, hazardous waste, Section 4(f) evaluations or substantial flood plain encroachments</li> </ul>
Stakeholders	<ul style="list-style-type: none"> <li>• No public controversy</li> </ul>

For each of the three project complexity scenarios, project location could significantly increase the complexity of a project due to traffic control challenges, for example an interstate mainline vs. mainline NHS routes (non-interstate) or an urban location versus a rural location. This could impact the ranges of contingency.

**Table A-2: Moderately Complex Project Complexity Definitions  
(Anderson et al. 2007)**

<b>Moderately Complex Projects</b>	
Roadway	<ul style="list-style-type: none"> <li>• 3R and 4R projects which do not add capacity.</li> </ul>
	<ul style="list-style-type: none"> <li>• Minor roadway relocations.</li> </ul>
	<ul style="list-style-type: none"> <li>• Certain complex (non-trail enhancements) projects.</li> </ul>
	<ul style="list-style-type: none"> <li>• Slides, subsidence.</li> </ul>
Traffic Control	<ul style="list-style-type: none"> <li>• Non-ITS but major safety improvements.</li> </ul>
	<ul style="list-style-type: none"> <li>• Interconnected traffic control/management projects.</li> </ul>
Structures	<ul style="list-style-type: none"> <li>• Non-complex (straight geometry with minimal skew; designs using AASHTO description factors; minimal seismic analysis; footings on rock or conventional piles and abutments) bridge replacements with minor (&lt;610m [2,000 ft]) roadway approach work.</li> </ul>
	<ul style="list-style-type: none"> <li>• Bridge rehabilitation which requires re-analysis of bridge capacity.</li> </ul>
	<ul style="list-style-type: none"> <li>• Bridge mounted signs.</li> </ul>
	<ul style="list-style-type: none"> <li>• Tie back walls.</li> </ul>
	<ul style="list-style-type: none"> <li>• Noise walls.</li> </ul>
	<ul style="list-style-type: none"> <li>• Proprietary/non-proprietary walls.</li> </ul>
Right-of-Way	<ul style="list-style-type: none"> <li>• Right-of-Way plans needed with less than 20 moderate to significant claims and very few relocations or displacements.</li> </ul>
Utilities	<ul style="list-style-type: none"> <li>• Some utility relocations, most of it prior to construction, but no major utility relocations.</li> </ul>
Environment	<ul style="list-style-type: none"> <li>• Categorical Exclusion level 2 or mitigated Environmental Assessment projects.</li> </ul>
	<ul style="list-style-type: none"> <li>• Cultural resources (historical, archeological, etc.). Coordination with Museum Commission, FHWA, and/or Advisory Council</li> </ul>
	<ul style="list-style-type: none"> <li>• Wetland mitigation</li> </ul>
	<ul style="list-style-type: none"> <li>• Parkland involvement</li> </ul>
	<ul style="list-style-type: none"> <li>• Water and air pollution mitigation</li> </ul>
	<ul style="list-style-type: none"> <li>• Major coordination with Game or Fish and Boat commissions</li> </ul>
	<ul style="list-style-type: none"> <li>• Endangered species</li> </ul>
Stakeholders	<ul style="list-style-type: none"> <li>• Involvement of public and public officials is moderate due to non-controversial project type</li> </ul>
	<ul style="list-style-type: none"> <li>• General communication about project progress is required</li> </ul>

**Table A-3: Most Complex Project Complexity Definitions  
(Anderson et al. 2007)**

<b>Most Complex (MAJOR) Projects</b>	
Roadway	<ul style="list-style-type: none"> <li>• New highways; major relocations</li> </ul>
	<ul style="list-style-type: none"> <li>• New interchanges</li> </ul>
	<ul style="list-style-type: none"> <li>• Capacity adding/major widening</li> </ul>
	<ul style="list-style-type: none"> <li>• Major reconstruction (4R; 3R with multi-phase traffic control)</li> </ul>
	<ul style="list-style-type: none"> <li>• Congestion Management Studies are required</li> </ul>
Traffic Control	<ul style="list-style-type: none"> <li>• Multi-phased traffic control for highway or bridge construction that would mandate CPM during construction</li> </ul>
	<ul style="list-style-type: none"> <li>• Major ITS (Electronic surveillance, linkages) corridor project</li> </ul>
Structures	<ul style="list-style-type: none"> <li>• Replacement, new or rehabilitation of:</li> </ul>
	Unusual (non conventional like segmental, cable stayed, major arches or trusses, steel box girders, movable bridges, etc.)
	Complex (sharp skewed (less than 70 degree) superstructure, non-conventional piers or abutments, horizontally curved girders, three dimensional structural analysis, non-conventional piles or caisson foundations, complex seismic analysis, etc.)
	Major (bridge cost of \$5 Million or more-Federal definition)
	Unusual formations (caissons, uncommon piles, mines, Karst situation)
Right-of-Way	<ul style="list-style-type: none"> <li>• Right-of-Way plans are needed and numerous relocations of residences or displacement of commercial and/or industrial properties are required. A few to over 20 property owners are involved. Major involvement of environmental clean-up. Before and after analysis</li> </ul>
Utilities	<ul style="list-style-type: none"> <li>• Major utility (transmission lines, substations) relocations or heavy multi-utility coordination is involved</li> </ul>
Environment	<ul style="list-style-type: none"> <li>• Environmental Impact Studies are required or complex Environmental Assessment without mitigated finding of no significant impact</li> </ul>
	<ul style="list-style-type: none"> <li>• Studies of multiple alternatives</li> </ul>
	<ul style="list-style-type: none"> <li>• Continued public and elected officials involvement in analyzing and selecting alternates</li> </ul>
	<ul style="list-style-type: none"> <li>• Other agencies (such as FHWA, COE, PHMC, Game Commission, Fish &amp; Boat Commission, DEP, DCNR, EPA, Agricultural Board, etc.) are heavily involved to protect air; water; games; fish, threatened and endangered species; cultural resources (historical, archaeological, parks, wetlands, etc), etc.</li> </ul>
Stakeholders	<ul style="list-style-type: none"> <li>• Controversial (lack of consensus) and high profile projects. (Fast track design/construction, high public impact, high interaction of elected officials, etc.)</li> </ul>
	<ul style="list-style-type: none"> <li>• Major coordination among numerous stakeholders is required.</li> </ul>

**Table A-4: Representative Risks (Non Complex Projects)**

<b>REPRESENTATIVE RISKS</b>
<b>Non-Complex (Minor) Projects</b>
Changes in Program Priorities
Contractor delays
Errors in cost estimating
Inaccurate assumptions on technical issues
Inaccurate design and construction time estimates
Lack of coordination of project personnel
Unrealistic project assumptions
Haul distances (and permitting for hauls on certain roads)
<i>Please note: This list is not exhaustive</i>

**Table A-5: Representative Risks (Moderately Complex Projects)**

<b>REPRESENTATIVE RISKS</b>
<b>Moderately Complex Projects</b>
<b><i>Includes all minor project risks and the following</i></b>
Geotechnical Issues
Changes to materials/foundation
New or revised design standards
Bridge redesign/analysis
Delays in permitting processes
Unidentified utilities
Shortage of Skilled labor
Insufficient planning time
Changes in funding priorities
Changes in environmental regulations
New requests from stakeholders
Non-competitive bidding environment
Haul distances (and permitting for hauls on certain roads)
<i>Please note: This list is not exhaustive</i>



**Table A-6: Representative Risks (Most Complex Projects)**

<b>REPRESENTATIVE RISKS</b>
<b>Most Complex (Major) Projects</b>
<i>Includes all minor and moderately complex project risks and the following</i>
Unresolved Constructability issues
Insufficient project data for environmental study
Historic site
Project scope and objectives not clearly defined
Design complexity
Unanticipated effects of inflation
Political factors
Incomplete design/bridge site data
Complex environmental requirements
Delays from reviewing agencies
Non-competitive bidding environment
Haul distances (and permitting for hauls on certain roads)
<i>Please note: This list is not exhaustive</i>

**APPENDIX B**  
**PANEL SELECTION**

## **Letter of Invitation to participants**

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## **Invitation to participate in a Delphi Study**

Dear <Title> <Name>

NCHRP project 8-60, “Guidebook on Risk Analysis tools and Management Practices to Control Transportation Costs”, is a research project funded by the National Cooperative Highway Research Program (NCHRP). The main objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs.

The research team for project 8-60 identified industry practice of state highway agencies with respect to risk management and project contingency allocation. Of the 48 agencies which responded to the questionnaires, most generally agreed that contingency is necessary in their cost estimates, though different methods are used in estimating this contingency. Furthermore the majority do not have any formal definition of contingency, without which agencies could have a difficult time consistently calculating appropriate contingencies.

This letter serves as an invitation to participate in a separate study which aims to develop a set of sliding scale contingencies applicable to US highway projects. A total of 25-40 other participants from the construction industry will make up the panel of experts for this study using the Delphi technique. Your input will be vital in determining ranges of contingency for three levels of project complexity – Major (most complex) projects, moderately complex projects, and Minor (non-complex) projects.

In the first round of questionnaires you would be provided with a matrix for three project types – Complex (major), moderately complex and non-complex (minor) projects across the planning, programming and design phases of project development. Using your expert judgment you would be required to provide appropriate contingency ranges for each of the phases of project development. The results of the entire group of Participants would be combined and analyzed by the researcher and forwarded to you as part of the second round of questionnaires. From the information at our disposal, it is expected that consensus would be achieved in not more than 3 rounds.

The first round of questionnaires would be mailed to you by <date>. Each round of questionnaires can be completed in 30-45 minutes. The results of round 1 would be included in the second round of questionnaires by <date>. If a third round is required, it would be mailed to you in the first week of <date>.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu). If you choose to participate, kindly fill out the participant data on the attached form and send it by email to the above address on or before <date>. Look forward to your participation in this survey.

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A and M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University

Enclosures:

- 1.) Overview of the Delphi Approach
- 2.) Participant Response Form

## Participant Information Form

Name:
Organization:
Number of years in the Transportation Industry:
Position:
Years in current position:
Address:
Phone:
Email:

In what area(s) of the Transportation Industry have you worked within the last 10-15 years, and how many years in each. Please specify below:

Area of primary responsibility	Number of years
Estimating and Risk experience	Number of years
Estimating Experience	
Risk Assessment Experience	

Would you qualify your exposure to Estimating and Risk Assessment Practices (during those years as indicated above) as <b>LOW, MEDIUM or HIGH</b>	Level of Exposure to Practices
Estimating	
Risk Assessment	

Please provide any additional comments about your experience in the space provided below

--

*The information requested here is intended to ascertain the level of professional experience of the participants in areas of expertise relevant to this study. All information provided by participants during this study is considered highly confidential and would be used solely for the purpose of this study.*

## Invitation Follow-up Letter

<Date>

<Title> <First Name> <Last Name>  
 <Company name>  
 <Company Address>

### Re: Invitation to participate in a Delphi Study

Dear <Title> <Name>,

Thank you for agreeing to participate in this NCHRP 8-60 related sliding scale contingency study. As mentioned in the email invitation you received on <date> you will be required, using your expert judgment, to provide appropriate contingency ranges for various levels of project definition using an Excel Spreadsheet.

The first round query would be emailed to you with instructions on <date>. Typically, one to two more rounds are required to achieve consensus among the expert panel. The input for each round should be completed in approximately 30 to 45 minutes with the first round effort closer to 45 minutes or more depending on the time taken to read the definitions and other support material provided.

Once again, thank you for your time, interest and cooperation.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu). My Graduate Research Assistant involved in this study, Niyi Olumide, would email the Excel Spreadsheet with instructions directly to you. His email address is [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
 Professor, Texas A & M University

Niyi Olumide  
 Graduate Research Assistant, CEM Program  
 Texas A & M University

**APPENDIX C**  
**ROUND 1 QUERY**

## **Background and Instructions, Round 1**

### Background

NCHRP Project 8-60 “Guidebook on Risk Analysis tools and Management Practices to Control Transportation Costs” is a research project funded by the National Cooperative Highway Research Program (NCHRP). The main objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs.

The research team for project 8-60 identified industry practice of state highway agencies with respect to risk management and project contingency allocation. Of the 48 agencies which responded to the questionnaires, most generally agreed that contingency is necessary in their cost estimates, though different methods are used in estimating this contingency. Furthermore the majority of agencies do not have any formal definition of contingency. Methods used to determine contingency values varied widely with most methods based on qualitative approaches, without specific rationale for these approaches.

This separate study aims to develop a set of sliding scale contingencies applicable to US highway projects. A total of 23 participants from the construction industry make up the panel of experts for this study using the Delphi technique. Your input will be vital in determining ranges of contingency for three levels of project complexity – Major (Most Complex) projects, Moderately Complex projects, and Minor (Non-Complex) projects.

### Instructions

You have been provided with three contingency matrices: one for minor projects, the second for moderately complex projects, and the third for major projects. In each of the columns labeled 'Contingency', provisions have been made for three values of contingency: low, most likely estimate (MLE), and high. Based on your expert judgment, you are asked to fill in ranges of contingency values for construction cost estimates corresponding to the outlined phases of project development and the particular level of complexity and project definition.

By clicking on the 'Project Complexities' tab, you will be able to view typical characteristics of minor, moderately complex and major projects, along with some representative risks for each category.

Definitions of some vital terms have been provided and can be viewed by clicking on the 'key definitions' tab, or by using the 'HELP' button provided in each matrix.

For convenience all worksheets have been carefully set up and are print ready to enable quick reference to study material provided if necessary.



The excel spreadsheet is expected to take 45 minutes to 1 hour to complete. Responses should be saved and sent via email to Stuart Anderson at s-anderson5@tamu.edu and Niyi Olumide at n-i-y-i@neo.tamu.edu by <date>.

Communication

Please direct any questions you may have to:

**Dr. Stuart Anderson, Ph.D.**

Department of Civil Engineering

3136 TAMU

Texas A & M University

College Station 77843-3136

Phone: (979) 845-2407

Fax: (979) 845-6554

Email: [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu)

### **Method Description**

The Conventional Delphi technique is a method used to gather opinions from a group of individuals. This information is analyzed and used to solve problems for which there is little or no empirical evidence. Therefore this technique relies more on the judgment of experts to achieve results.

The iterative process of information gathering is done by administering a series of questionnaires called rounds to a panel of experts and giving controlled feedback to the respondents after each round. The aim of the Delphi technique is to achieve a consensus among the group of experts. The number of rounds could vary but is typically a minimum of three rounds; however, the number of rounds could be less if consensus is achieved sooner. The first round is typically more exploratory and identifies issues which would be further addressed in subsequent rounds. Responses from the first round are compiled and form the basis for the second round; they are presented to the participants who would then have an opportunity to revise their earlier judgment/opinion if necessary in the light of new information. Subsequent rounds if required are conducted in a similar manner until consensus is achieved.

One key feature of the Delphi process is anonymity among the expert panel; panelists would not necessarily know one another nor would they know the source of each of the other responses. This eliminates intimidation, persuasion, individual dominance, conflict and the effects of status, and other drawbacks of face-to-face interaction. The use of controlled feedback to the participants ensures that panelists can revise their earlier opinions easily in the light of new evidence.

This methodology has been applied to problem solving or forecasting in the field of medicine, nursing, information science, engineering and in the construction industry.

## **Key Definitions**

Planning: The project development phase that includes identifying and assessing transportation system needs, developing the initial design concept and scope of projects that would address those needs, crafting project purpose and need, considering environmental factors, facilitating public involvement/participation, and considering a proposed project in the larger context of the transportation system and the affected community.

Programming/ Preliminary Design: The project development phase that includes conducting environmental analysis, conducting schematic development, holding public hearings, determining right-of-way impact, determining project economic feasibility, obtaining funding authorization, developing right-of-way needs, obtaining environmental clearance, determining design criteria and parameters, surveying utility locations and drainage, and making preliminary plans such as alternative selections, assign geometry, and create bridge layouts.

Design: The project development phase that includes acquiring right-of-way; developing plans, specifications, and estimates (PS&E), that is, finalizing pavement and bridge design, traffic control plans, utility drawings, hydraulics studies/drainage design, and cost estimates.

Level of Definition: A description of project construction requirements and attributes to include technical and site related information (often referred to as the project scope). The level of definition increases from the planning phase to the final PS&E phase of Project Development. At one extreme, early planning estimates are defined only by major parameters (1 to 5 percent complete definition), while at the other extreme, the plans and specifications are complete (100 percent).

Base Estimate: The most likely project estimate, exclusive of Project Contingency, for known costs for all known construction work.

Contingency: An estimate of costs associated with identified uncertainties and risks, the sum of which is added to the Base Estimate to complete the Project Cost Estimate. Contingency is expected to be expended during the project development and construction process. For the purpose of this study, please provide three assessments of contingency for each phase of project development: Low, Most Likely Estimate (MLE), and High for each project type.

Historic Data: Cost estimates are based on historic data. The nature of this historic data is often different depending on the estimate types. Historic contractor bids captured by the DOT are used to support bid based estimating. Past similar project unit cost data is often used to support bid based estimating when the past project is very similar to the project being estimated. Specific categories of data are used to support cost based

estimating including crew sizes and wage rates, crew production rates, material costs, equipment production rates and costs, and contractor overhead and profit costs. Percentages to support allowances are often based on past projects using a similar set of bid items that cover an element of work (e.g., drainage)

Estimate Type: The type of estimating method varies with the level of project definition and therefore, project development phase. The following categorization of estimate types is used:

- Planning - Parametric estimating where costs are estimated using major project parameters such as lane miles, square foot of bridge deck area, and percentage of construction cost.
- Programming - Bid based estimating where major items are identified (80% of costs in 20% of items) in combination with some cost based estimating and percentages.
- Design - Bid based estimating where most items are identified as the design is prepared in combination with some cost based estimating and percentages.
- PS & E - Bid based and/or cost based estimating where all items (pay) are identified.

## Letter of Transmittal, Round 1

<Date>

<Title> <First Name> <Last Name>

## Letter of Transmittal, Round 1 Query

Dear Participant,

Thank you once again for agreeing to participate in this NCHRP 8-60 related sliding scale contingency study.

In the first section of the attached spreadsheet labeled 'Participant Information' general information about you is requested. Subsequent sections include Method description, Background and Instructions, Project Complexities and Key definitions. The last section (Contingency Matrices) contains the matrices for each Project type/Complexity into which you are requested to input appropriate contingency ranges using your expert judgment.

The excel spreadsheet has been tested; the input should be completed in approximately 45 minutes to 1 hour depending on the time taken to read the definitions and other support material provided. For convenience all worksheets have been carefully set up and are print ready to enable quick reference to study material provided if necessary.

Please complete the attached excel spreadsheet and return by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu) by <date>.

The 2<sup>nd</sup> round query containing a summary of the initial responses would be forwarded to you by email within two to three weeks from <date>.

Thank you for your cooperation thus far. For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

The participant information requested is intended to ascertain the level of professional experience of the participants in areas of expertise relevant to this study. All information provided by participants during this study is considered highly confidential and would be used solely for the purpose of this study.

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A and M University

Niyi Olumide  
Graduate Research Assistant, CEM  
Texas A and M University

## First Reminder, Round 1

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## First Reminder, Round 1 Query

Mr. /Ms.....,

The Round 1 query of the sliding scale contingency study was sent to you on <date>. Fifteen (15) out of twenty-three (23) responses have been received to date from other members of the panel of experts. Your input is vital in determining the ranges of contingency in this study. The research team expected to have all completed responses in by <date> to facilitate further analysis of the results.

We would appreciate receipt of your completed response at your earliest convenience before <date> by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

We understand that there are numerous demands on your time and appreciate your cooperation thus far.

The round 2 query containing a summary of the initial responses would be forwarded to you by <date>.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A and M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A and M University

## Second Reminder, Round 1

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## Second Reminder, Round 1 Query

Mr. /Ms.....,

The Round 1 query of the sliding scale contingency study was sent to you on <date>. Twenty (20) out of twenty-three (23) responses have been received to date from other members of the panel of experts. Your input is vital in determining the ranges of contingency in this study. The research team expected to have all completed responses in by <date> to facilitate further analysis of the results.

We would appreciate receipt of your completed response at your earliest convenience before <date> by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

We understand that there are numerous demands on your time and appreciate your cooperation thus far.

The round 2 query containing a summary of the initial responses would be forwarded to you by <date>.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A and M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A and M University

**APPENDIX D**  
**ROUND 2 QUERY**



## **Background and Instructions, Round 2**

### Background

NCHRP Project 8-60 “Guidebook on Risk Analysis tools and Management Practices to Control Transportation Costs” is a research project funded by the National Cooperative Highway Research Program (NCHRP). The main objective is to develop a comprehensive guidebook on risk-related analysis tools and management practices for estimating and controlling transportation project costs.

The research team for project 8-60 identified industry practice of state highway agencies with respect to risk management and project contingency allocation. Of the 48 agencies which responded to the questionnaires, most generally agreed that contingency is necessary in their cost estimates, though different methods are used in estimating this contingency. Furthermore the majority of agencies do not have any formal definition of contingency. Methods used to determine contingency values varied widely with most methods based on qualitative approaches, without specific rationale for these approaches.

This separate study aims to develop a set of sliding scale contingencies applicable to US highway projects. A total of 23 participants from the construction industry make up the panel of experts for this study using the Delphi technique. Responses were received from all participants in the round 1 query. Your input for the round 2 query will be vital in determining ranges of contingency for three levels of project complexity – Major (Most Complex) projects, Moderately Complex projects, and Minor (Non-Complex) projects.

### Instructions

All 23 participants that make up the expert panel responded to the round 1 query of this study. This is the round 2 query. The spreadsheet contains vital information from the round 1 group results that would be instrumental in determining your response to this round. Please go over the information before providing your response.

This spreadsheet contains seven (7) sections. Section 1 ‘Background and Instructions’ contains detailed instructions particularly suited to this round. Section 2 ‘Method’ describes the Delphi approach. Section 3 ‘Project Complexities’ contains descriptions of the different project types. Section 4 ‘Key definitions’ contains explanations of some of the terms used in this study. Section 5 ‘Group Summary Statistics’ contains an overview and a quantitative summary of the round 1 result. Section 6 ‘Respondents’ comments’ contains an aggregate of comments received from respondents in round 1. Section 7 ‘Matrices’ contains three matrices, one for each Project type/Complexity, into which you are requested to input appropriate contingency ranges using your expert judgment. The three matrices provided contain your response to the round 1 query and the means of the aggregate group response for the round 1 query. Additional space is provided for your

response in round 2. In each of the columns labeled 'construction contingency range' please input values for the low, most likely estimate (MLE) and high.

Based on the group summary of the round 1 query please review your round 1 responses for each project complexity category. You may decide to change your responses after reviewing all round 1 input from the group (note: if you do not wish to change your response, please input your round 1 values). Please provide specific comments supporting your round 2 input especially if your response deviates substantially from the group mean ratings. Your comments will provide justification for any deviations from the group mean in the results and will be very important if a third and final round is required to achieve consensus.

By clicking on the 'Project Complexities' tab, you will be able to view typical characteristics of minor, moderately complex and major projects, along with some representative risks for each category.

Definitions of some vital terms have been provided and can be viewed by clicking on the 'key definitions' tab, or by using the 'HELP' button provided in each matrix.

For convenience all worksheets have been carefully set up and are print ready to enable quick reference to study material provided if necessary.

The excel spreadsheet is expected to take 45 minutes to 1 hour to complete. Responses should be saved and sent via email to Stuart Anderson at s-anderson5@tamu.edu and Niyi Olumide at n-i-y-i@neo.tamu.edu by <date>.

Communication

Please direct any questions you may have to:

**Dr. Stuart Anderson, Ph.D.**

Department of Civil Engineering

3136 TAMU

Texas A & M University

College Station 77843-3136

Phone: (979) 845-2407

Fax: (979) 845-6554

Email: [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu)

**Table D-1: Respondents' Comments from Round 1**

Below are comments received from some of the panel members in the round 1 query. Each block of comments represents input from one panel member. The panel members did not necessarily provide comments for every input. Shown below are the sections in which comments were provided. The contingency values input by each panel member are shown to provide a basis for understanding the comments provided. The project type and phases of project development shown correspond to the sections where comments were provided by each panel member.

Project Type	Phase	Low	MLE	High	Comments per respondent by project type and phase
Non Complex	Planning (1 - 3%)	20	40	60	It is not so much about project definition but about future costs.
	Programg (5 - 15%)	20	40	60	Even in this time range hard to guestimate costs. Too many external factors can change the situation.
	Design (15 - 40%)	10	30	40	Starting to feel better and now it is time to pay close attention to project details.
Most Complex	Design (75 - 100%)	30	50	70	What I know about so many complex projects is causing we to keep high percentages.

Non Complex	Planning (1 - 3%)	15	20	25	I am assuming that the cost per mile is based on past projects of similar type and those costs include costs of risks that were realized, ie culverts and turnlanes.
	Design (15 - 40%)	10	11	13	Ideally you have a comprehensive scope that defines the project very well.
	Design (70 - 100%)	5	6	7	These costs are for cost overruns and change orders during construction.
Moderately Complex	Planning (4 - 7%)	20	25	35	If you have good comparable projects this could be lower, but I think it is better to error on high side.
	Design (25 - 35%)	12	17	22	This could really depend on how well you feel the project is scoped, is there a lot of questions that are left to be answered or do you feel you have a good understanding of the project.
	Design (70 - 100%)	6	8	12	These costs are for cost overruns and change orders during construction.
Most Complex	Planning (7 - 15%)	30	35	45	If you have good comparable projects this could be lower, but I think it is better to error on high side.
	Programg (15 - 35%)	20	25	35	There are more risk involved with the public involvement and what influences local governments will have on the scope of the project
	Design (75 - 100%)	6	8	12	These costs are for cost overruns and change orders during construction.

Non Complex	Planning (1 - 3%) (Comment applies to all phases, and all project types)	50	100	200	FOR ALL ITEMS ON ALL LISTS: a.) "Contingencies" does not include an allowance for escalation / inflation. b.) I am uncomfortable with the technique of applying a contingency to the estimate. It would be better to do risk analysis and always give costs estimates as a range. E.g. "I am 95% certain that the cost will be between \$1 Million and \$5 Million." Although decision-makers might want more precise answers, anything more precise would be misleading.

Non Complex	Design (70 - 100%)	3	5	10	MLE matches our policy for simple pavement preservation projects
Most Complex	Design (75 - 100%)	7	10	15	MLE matches our policy

Moderately Complex	Design (25 - 35%)	50	75	100	Assume project alternative not yet finalized (despite 30% design). A number of major uncertainties might remain
Most Complex	Planning (7 - 15%) (Comment also applies to Non Complex & Moderately Complex)	100	150	200	General comment: All of the contingency values I've entered reflect the range of "equivalent contingencies" (e.g., 90th percentile YOE cost minus base cost in current dollars) observed from results of probabilistic, risk-based assessments, and reflect the combined impact from cost risk, schedule risk, and inflation risk. Our experience, however, is that design teams often do not account for schedule risk and inflation risk in their contingencies (they might account for inflation on the base schedule as a line item). <u>These values exclude allowances for items that are known to be required as part of the base project, but that are not yet quantified in the cost estimate.</u>
	Program (15 - 35%)	100	150	200	Just as many uncertainties this far from letting.
	Design (35 - 75%)	75	125	150	I know this says 'Design', but the up to '4 years from letting' qualifier is a big risk flag for me. We often see the most complex projects still facing very large uncertainties during design (e.g., still working on environmental documentation, still defining or refining scope / project alternatives, etc.) up to a year from letting. In addition, complex projects often have a higher likelihood of legal challenges, funding delays, adverse market conditions, etc. All of these issues can result in delay and/or increased cost.
	Design (75 - 100%)	50	75	100	Assume this is after uncertainty in the project alternative has truly been resolved. However, a number of the issues listed in the cell above are still possible.

<b>Non Complex</b>	<b>Planning (1 - 3%)</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	Contingencies are not meaningful as you really don't have a project yet
	<b>Programg (5 - 15%)</b>	<b>20</b>	<b>24</b>	<b>28</b>	Experience with projects at this stage of planning is very limited
<b>Moderately Complex</b>	<b>Planning (4 - 7%)</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	Contingencies are not meaningful as you really don't have a project yet. Experience with projects at this stage of planning is very limited
	<b>Programg (15 - 25%)</b>	<b>20</b>	<b>28</b>	<b>40</b>	Experience with projects at this stage of planning is very limited
<b>Most Complex</b>	<b>Planning (7 - 15%)</b>	<b>28</b>	<b>52</b>	<b>80</b>	Experience with projects at this stage of planning is very limited

<b>Non Complex</b> (Comments and values are identical to those in Moderately Complex & Most Complex)	<b>Planning (1 - 3%)</b>	<b>30</b>	<b>35</b>	<b>50</b>	Initiating Functional Units (Maintenance, Traffic, and Planning) typically develop a feasibility study (conceptual Report) which defines the initial project scope.
	<b>Programg (5 - 15%)</b>	<b>25</b>	<b>25</b>	<b>25</b>	Each estimate also includes 5-10% for Minor Items and 5% for Supplemental Work that cannot be identified at the time of the estimate except for Plans, Specifications, & Estimate. These items of work must be quantified in the final estimate.
	<b>Design (15 - 40%)</b>	<b>20</b>	<b>20</b>	<b>20</b>	
	<b>Design (40 - 70%)</b>	<b>15</b>	<b>15</b>	<b>15</b>	The estimates are updated at least annually between these Project Development milestones. Estimates are also updated when additional information becomes available (e.g. hazard waste reports, geotechnical reports, etc).
	<b>Design (70 - 100%)</b>	<b>5</b>	<b>10</b>	<b>15</b>	Contingency is a reflection of level of confidence. As a project is developed, the number of unknowns is reduced. At 100% we are required to have the contingency level at 5%.

<b>Non Complex</b>	<b>Planning (1 - 3%)</b>	<b>20</b>	<b>25</b>	<b>30</b>	Non Complex projects don't typically take 10 to 20 years to develop
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<b>Non Complex</b>	<b>Planning (1 - 3%)</b>	<b>0</b>	<b>10</b>	<b>25</b>	We do not use a contingency. We update our per Lane mile costs annually and update our estimates annually. Thus I think 0 is always a valid contingency.
	<b>Design (40 - 70%)</b>	<b>0</b>	<b>5</b>	<b>10</b>	One of the major problems is dealing with scope creep.
<b>Most Complex</b>	<b>Planning (7 - 15%)</b>	<b>0</b>	<b>20</b>	<b>40</b>	It is hard to keep track of different alternates for projects that are required for the EIS analysis. To compensate for that I used a higher construction contingency.
	<b>Programg (15 - 35%)</b>	<b>0</b>	<b>15</b>	<b>30</b>	These projects usually have more money that is spent on environmental issues that is hard to pin down so far away from construction time.
	<b>Design (35 - 75%)</b>	<b>0</b>	<b>10</b>	<b>25</b>	Rules in the environmental area change rapidly and we spend a lot of money that is difficult to quantify.

<b>Non Complex</b>	<b>Planning (1 - 3%)</b>	<b>10</b>	<b>20</b>	<b>20</b>	Very seldom do these projects end up in the long range plan in a form that represents that final project.
	<b>Programg (5 - 15%)</b>	<b>10</b>	<b>20</b>	<b>20</b>	Many of these projects especially the maintenance/overlay projects don't show up in the STIP (Transportation Improvement Plan) until the last year as defined projects.
	<b>Design (70 - 100%)</b>	<b>5</b>	<b>5</b>	<b>5</b>	Figures are exclusive of funds available for cost adjustments driven by predetermined market factors and incentives.
<b>Moderately Complex</b>	<b>Design (70 - 100%)</b>	<b>5</b>	<b>7</b>	<b>10</b>	Figures are exclusive of funds available for cost adjustments driven by predetermined market factors and incentives.
<b>Most Complex</b>	<b>Design (35 - 75%)</b>	<b>7</b>	<b>10</b>	<b>15</b>	Figures are exclusive of funds available for cost adjustments driven by predetermined market factors and incentives.

<b>Non Complex</b>	<b>Planning (1 - 3%)</b>	<b>10</b>	<b>50</b>	<b>100</b>	High risk due to length of time prior to letting. Commodity price risks.
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## Transmittal Round 2

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## Letter of Transmittal, Round 2 Query

Dear Participant,

Thank you once again for agreeing to participate in this NCHRP 8-60 related sliding scale contingency study and for your input in the round 1 query. Please find attached the round 2 query. The goal of this round 2 query is to work toward achieving consensus by sharing all the respondents' replies with you and providing an opportunity for you to adjust your assessment given this new information.

The attached spreadsheet contains seven (7) sections as follows:

1. Section 1 'Background and Instructions' contains detailed instructions particularly suited to this round. Please read them carefully before you proceed to subsequent sections.
2. Section 2 'Method' describes the Delphi approach (same as round 1).
3. Section 3 'Project Complexities' contains descriptions of the different project types (same as round 1).
4. Section 4 'Key definitions' contains explanations of some of the terms used in this study (same as round 1).
5. Section 5 'Group Summary Statistics' contains an overview and a quantitative summary of the round 1 result.
6. Section 6 'Respondents' comments' contains an aggregate of comments received from respondents in round 1.
7. Section 7 'Matrices' contains three matrices, one for each Project Type/Complexity, into which you are requested to input appropriate contingency ranges using your expert judgment.

The three matrices in Section 7 contain your response to the round 1 query and the mean of the aggregate group responses for the low, most likely, and high values based on round 1 input. Additional space is provided for your response in round 2.

Based on the group summary of the round 1 query please review your round 1 responses for each project complexity category. You may decide to change your responses after reviewing all round 1 input from the group (note: if you do not wish to change your response, please input your round 1 values). Please provide specific comments supporting your round 2 input *especially if your response deviates substantially from the*

*group mean ratings*. Your comments will provide justification for any deviations from the group mean in the results and will be very important if a third and final round is required to achieve consensus.

We want you to consider two points we think may need clarification: 1) The “construction contingency range” (column response headings in the matrices) is applied to estimate scope that will be covered in the Engineer’s Estimate and excludes, for example, right-of-way, preliminary engineering and design, and construction engineering and administration costs; 2) The contingency values, therefore, should represent an estimate of costs associated with uncertainties and risks in project development up to the time of letting and the cost of contingency that is included for changes and unit price adjustments during construction. If your SHA policy dictates a construction contingency after letting (e.g., for change orders and changes in quantities), please note that amount (e.g., 4%) in the comments section.

Please complete the attached excel spreadsheet and return by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu) by <date>.

Should a third round be required you will be notified in advance and the round 3 query containing a summary of the round 2 responses would be forwarded to you by email thereafter.

Thank you for your cooperation thus far. For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University



## First Reminder, Round 2

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## First Reminder, Round 2 Query

Mr. /Ms.....,

The Round 2 query of the sliding scale contingency study was sent to you on <date>. Twelve (12) out of twenty-three (23) responses have been received to date from other members of the panel of experts. The research team expected to have all completed round 2 responses in by <date>.

We would appreciate receipt of your completed response at your earliest convenience before <date> by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

The round 2 results would be analyzed as soon as all outstanding responses have been received. If a third round is required to achieve consensus you will be notified in advance and the round 3 query containing a summary of the round 2 responses would be forwarded to you by email thereafter.

We appreciate your time, effort and cooperation thus far.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University

## Second Reminder, Round 2

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

## Second Reminder, Round 2 Query

Mr. /Ms.....,

The Round 2 query of the sliding scale contingency study was sent to you on <date>. Eighteen (18) out of twenty-three (23) responses have been received to date from other members of the panel of experts. The research team expected to have all completed round 2 responses in by <date> to facilitate further analysis of the results.

In the round 1 query, twenty-three responses (23) were received from all members of the panel of experts. For consistency in the results, your input is very vital in determining the ranges of contingency in the 2nd round of this study. We would appreciate receipt of your completed response at your earliest convenience before <date> by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

We understand that there are numerous demands on your time and appreciate your cooperation thus far.

For more information contact Dr. Stuart Anderson via phone at [979-845-2407](tel:979-845-2407) or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University

### **Third Reminder, Round 2**

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

### **Third Reminder, Round 2 Query**

Mr. /Ms.....,

The Round 2 query of the sliding scale contingency study was sent to you on <date>. Twenty-one (21) out of twenty-three (23) responses have been received to date from other members of the panel of experts. The research team expected to have all completed round 2 responses in by <date>.

We would appreciate receipt of your completed response at your earliest convenience before <date> by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

The round 2 results will be analyzed as soon as all outstanding responses have been received. If a third round is required to achieve consensus you will be notified in advance and the round 3 query containing a summary of the round 2 responses would be forwarded to you by email thereafter.

We appreciate your time, effort and cooperation thus far.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University

**APPENDIX E**  
**ROUND 3 QUERY**

### Instructions, Round 3

The response rates for the round 1 and round 2 queries were 100% (responses were received from all 23 members of the expert panel). The round 3 query is a consolidation round to ensure that consensus or stability of results is achieved. Your response in this round is therefore very vital to maintain consistency of the results across the 3 rounds and in the final results of the study.

This spreadsheet contains two (2) sections. Section 1 'Round 1 vs. Round 2' is a comparison of summary level statistics for the round 1 and round 2 queries. Please review the details provided in this section and proceed to section 2 if you wish to review your earlier assessment based on the group summary of the round 2 query. Please note that if you do not wish to change your response, you only need to reply "YES" to the round 3 email; you would not be required to fill out the matrices provided in section 2.

Section 2 'Contingency Matrices' contains three matrices, one for each Project type/Complexity, into which you are requested to input appropriate contingency ranges ONLY in the project categories where your round 3 assessment may differ from your earlier (round 2 ) assessment. The three matrices provided contain your response to the round 2 query and the means of the aggregate group response for the round 2 query. Additional space is provided for your response in round 3. You are only required to provide values in this section if you wish to review your earlier assessment based on new information from the round 2 query.

Responses should be forwarded via email to Stuart Anderson at s-anderson5@tamu.edu and Niyi Olumide at n-i-y-i@neo.tamu.edu by <date>.

#### Communication

Please direct any questions you may have to:

**Dr. Stuart Anderson, Ph.D.**

Department of Civil Engineering

3136 TAMU

Texas A & M University

College Station 77843-3136

Phone: (979) 845-2407

Fax: (979) 845-6554

Email: [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu)

### **Transmittal Round 3**

<Date>

<Title> <First Name> <Last Name>

<Company name>

### **Letter of Transmittal, Round 3 Query**

Dear Participant,

Please find attached the Round 3 Query of the Sliding Scale Contingency Study. The aim of this 3<sup>rd</sup> and final round is to work toward achieving consensus or stability in the results. Your response is very vital in this round to ensure consistency in the final results. The attached spreadsheet contains three (3) sections:

#### **Section 1 – Instructions**

#### **Section 2 (*Required*) - 'Round 1 vs. Round 2'**

This is a comparison of summary level statistics for the Round 1 and Round 2 Queries. Please review the details provided in this Section (2) and proceed to Section 3 only if you wish to review your earlier assessment based on the group summary of the Round 2 Query.

Please note that if you do not wish to change your response, you only need to reply "YES" to the Round 3 email indicating that you wish to maintain your Round 2 response; in this case, you would NOT be required to fill out the matrices provided in Section 3.

#### **Section 3 (*Optional*) - 'Contingency Matrices'**

You are only required to provide values in this section if you wish to change your earlier assessment based on new information (in the previous Section - 2) from the Round 2 Query. Contingency ranges should be provided ONLY in the project categories where your Round 3 assessment differs from your earlier (Round 2 Query) assessment.

Please complete the attached excel spreadsheet and return by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu) by <date>.

We continue to count on your patience and your expert judgment. Thank you for your cooperation thus far. For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A and M University

Niyi Olumide  
Graduate Research Assistant, CEM  
Texas A and M University

### **First Reminder Round 3**

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

### **First Reminder, Round 3 Query**

Dear Participant,

The Round 3 query of the sliding scale contingency study was sent to you on <date>. Seventeen (17) out of twenty-three (23) responses have been received so far from other members of the panel of experts.

We would appreciate receipt of your response at your earliest convenience before <date> to facilitate final analysis and compilation of the results.

If you would like to maintain your round 2 responses in round 3 reply YES to the round 3 email. Remember that you would need to complete the matrix (input appropriate contingency ranges where you wish to change your earlier assessment) only if you are not comfortable with your round 2 response based on the round 2 group summary. Please refer to the round 3 email received on <date> for more details.

Responses may be forwarded by email to [s-anderson5@neo.tamu.edu](mailto:s-anderson5@neo.tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

We appreciate your cooperation so far.

For more information contact Dr. Stuart Anderson via phone at 979-845-2407 or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University



### Second Reminder Round 3

<Date>

<Title> <First Name> <Last Name>

<Company name>

<Company Address>

### Second Reminder, Round 3 Query

Dear Participant,

Thank you for your input so far in this study. The research team still awaits your response to the round 3 query. To date, twenty-two (22) out of twenty-three (23) responses have been received. Your response is vital in determining the final results and to ensure consistency across the three rounds of this study. The research team intends to start compiling the final results by <date>. We would appreciate receipt of your response as soon as possible at your earliest convenience.

Responses may be forwarded by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu) and [n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu).

Please see previous emails for any further details.

Thank you.

For any additional information either contact Niyi Olumide ([n-i-y-i@neo.tamu.edu](mailto:n-i-y-i@neo.tamu.edu)) or contact Dr. Stuart Anderson via phone at [979-845-2407](tel:979-845-2407) or by email to [s-anderson5@tamu.edu](mailto:s-anderson5@tamu.edu).

Thank you.

Sincerely,

Stuart D. Anderson, Ph.D., P.E.  
Professor, Texas A & M University

Niyi Olumide  
Graduate Research Assistant, CEM Program  
Texas A & M University

**APPENDIX F**  
**RAW DATA RECEIVED FROM PARTICIPANTS IN ROUNDS 1, 2 AND 3**

**Table F-1: Round 1 Data from 23 Participants (Non Complex Projects)**

Round 1 Data	Non Complex (Minor) Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	0	0	0	20	24	28	12	16	20	8	12	16	4	8	12
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	50	100	200	35	70	150	25	50	100	15	30	60	5	10	20
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	15	25	30	12	20	25	10	15	20	6	12	17	5	10	15
6	15	25	25	10	15	25	5	10	15	0	5	10	0	0	5
7	10	30	40	10	30	40	10	20	20	5	10	10	5	10	10
8	10	25	40	10	20	30	5	15	25	5	10	15	0	5	10
9	15	20	25	12	14	16	10	11	13	8	10	12	5	6	7
10	10	15	20	8	12	20	5	8	15	3	5	10	0	3	5
11	0	10	25	0	10	20	0	10	15	0	5	10	0	2	5
12	10	15	20	8	10	12	6	8	10	4	5	6	2	3	4
13	20	25	30	20	25	30	15	18	20	5	8	10	0	3	5
14	35	50	60	35	40	45	30	35	40	25	30	35	15	20	25
15	40	100	200	40	100	200	40	50	100	20	35	50	10	20	50
16	10	20	20	10	20	20	10	10	15	5	10	10	5	5	5
17	15	20	25	13	15	20	10	13	15	7	10	13	3	5	10
18	30	40	50	20	30	40	15	20	25	10	12.5	15	7.5	10	12.5
19	10	50	100	10	30	50	10	25	30	5	10	20	4	5	10
20	50	100	200	40	80	160	30	60	120	20	40	80	10	20	40
21	25	25	25	25	25	25	10	15	20	10	15	20	5	10	10
22	20	40	60	20	40	60	10	30	40	10	20	30	10	15	20
23	50	75	100	50	75	100	25	50	75	10	20	30	5	10	15

**Table F-2: Round 1 Data from 23 Participants (Moderately Complex Projects)**

Round 1 Data	Moderately Complex Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	0	0	0	20	28	40	16	24	36	12	20	32	8	12	20
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	70	150	300	40	80	150	30	60	120	15	35	70	5	15	30
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	20	25	35	20	25	30	15	20	25	10	15	20	7	15	20
6	15	25	30	15	20	25	10	20	20	5	10	15	0	5	10
7	30	40	50	35	40	45	20	30	40	7	10	15	5	10	12
8	10	30	50	10	25	40	10	20	30	10	15	20	5	10	15
9	20	25	35	15	20	25	12	17	22	10	12	15	6	8	12
10	20	30	40	20	25	30	10	18	25	5	12	15	0	8	10
11	0	10	25	0	10	20	0	10	15	0	5	10	0	2	5
12	15	20	25	10	15	20	8	10	12	3	5	8	2	3	5
13	30	35	40	20	25	30	15	20	25	10	15	20	2	3	5
14	40	50	60	35	40	45	30	35	40	25	30	35	15	20	25
15	40	200	300	40	150	200	40	75	150	40	50	60	20	30	50
16	20	25	35	15	20	30	10	15	20	7	10	15	5	7	10
17	20	25	30	15	20	25	10	15	20	8	13	15	6	8	12
18	60	75	90	30	40	50	20	25	30	15	20	25	10	15	20
19	20	100	150	20	50	100	10	30	50	5	20	30	5	10	15
20	75	150	300	60	120	240	45	90	180	30	60	120	15	30	60
21	25	30	50	25	30	50	15	20	25	10	15	20	5	10	15
22	25	40	70	25	40	65	20	30	40	20	25	30	20	25	30
23	100	150	200	100	150	200	50	75	100	25	50	75	10	20	30

**Table F-3: Round 1 Data from 23 Participants (Most Complex Projects)**

Round 1 Data	Most Complex (Major) Projects											
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2		
Yrs from letting	10 to 20			5 to 10			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	28	52	80	20	36	56	16	28	44	12	20	32
2	40	40	40	40	40	40	20	20	20	5	5	5
3	100	200	400	50	100	200	20	40	80	10	20	40
4	30	35	50	25	25	25	15	15	15	5	10	15
5	25	30	40	15	25	35	12	20	30	10	20	25
6	25	40	50	25	25	40	10	15	25	5	10	15
7	40	50	60	30	40	50	20	30	40	10	20	30
8	25	50	75	10	30	50	10	20	30	5	10	15
9	30	35	45	20	25	35	12	15	20	6	8	12
10	25	40	50	20	25	35	10	15	20	3	10	15
11	0	20	40	0	15	30	0	10	25	0	5	20
12	25	35	45	20	25	30	5	10	15	3	5	8
13	40	45	50	20	25	30	15	20	25	5	10	15
14	40	50	60	35	40	45	30	35	40	20	30	35
15	100	250	500	100	200	500	40	60	75	20	50	70
16	20	30	35	15	20	25	10	15	20	7	10	15
17	25	30	35	20	25	30	13	18	23	7	10	15
18	70	85	100	40	55	70	20	30	40	10	15	20
19	50	125	200	25	75	150	10	25	40	5	10	20
20	100	200	400	80	160	320	60	120	240	40	80	160
21	25	35	50	25	35	50	15	25	35	5	7	10
22	50	70	100	50	65	80	40	60	80	30	50	70
23	100	150	200	100	150	200	75	125	150	50	75	100

**Table F-4: Round 2 Data from 23 Participants (Non Complex Projects)**

Round 2 Data	Non Complex (Minor) Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	50	100	200	35	70	150	25	50	100	15	30	60	5	10	20
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	15	25	30	12	20	25	10	15	20	6	12	17	5	10	15
6	15	25	30	10	15	25	5	10	15	0	5	10	0	0	5
7	20	40	60	20	30	50	14	23	34	7	15	20	5	9	12
8	0	0	0	0	0	0	10	20	30	5	10	20	0	5	10
9	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
10	15	25	40	15	25	40	10	15	30	5	12	25	5	8	15
11	0	25	38	0	20	33	0	15	23	0	10	15	0	5	8
12	25	35	55	20	30	40	15	20	25	8	10	12	3	5	7
13	20	25	30	20	25	30	15	18	20	8	12	15	3	6	8
14	30	45	60	30	35	45	25	30	35	20	25	30	10	15	20
15	40	100	200	40	100	200	40	50	100	20	35	50	10	20	50
16	20	30	40	15	20	25	10	10	15	5	8	10	5	5	5
17	18	23	30	15	20	30	11	17	22	9	12	15	4	7	12
18	25	40	50	20	30	40	15	20	25	10	15	20	8	10	13
19	25	40	100	20	35	50	15	25	35	10	15	25	5	8	15
20	50	100	200	40	80	160	30	60	120	20	40	80	10	20	40
21	25	35	50	25	25	35	10	15	25	10	15	20	5	10	10
22	20	40	60	20	40	60	10	30	40	10	20	25	10	15	20
23	25	50	75	25	40	60	20	35	50	10	15	25	5	10	15

**Table F-5: Round 2 Data from 23 Participants (Moderately Complex Projects)**

Round 2 Data	Moderately Complex Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	70	150	300	40	80	150	30	60	120	15	35	70	5	15	30
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	20	25	35	20	25	30	15	20	25	10	15	20	7	15	20
6	20	30	35	15	20	25	10	20	20	5	10	15	0	5	10
7	30	55	80	25	40	60	20	30	45	10	20	30	7	14	20
8	0	0	0	20	40	60	15	25	40	10	20	30	5	10	15
9	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
10	25	40	55	25	35	50	15	25	40	10	20	30	5	10	20
11	0	25	56	0	20	44	0	15	30	0	10	21	0	5	12
12	30	50	75	25	35	60	20	30	40	10	15	20	5	8	10
13	30	35	40	20	25	35	15	20	25	10	15	20	7	8	10
14	40	50	60	35	40	45	25	35	40	20	25	30	15	20	25
15	40	200	300	40	100	200	40	75	150	40	50	60	20	30	50
16	20	30	40	20	30	35	15	20	30	10	15	20	5	7	10
17	25	30	40	20	25	30	15	20	25	11	16	21	7	10	14
18	60	75	90	30	45	60	20	30	40	15	20	25	10	15	20
19	30	75	125	25	50	100	20	30	50	10	20	30	5	10	20
20	75	150	300	60	120	240	45	90	180	30	60	120	15	30	60
21	35	50	75	25	35	50	20	25	35	15	20	25	7	10	15
22	30	45	75	30	40	65	20	30	45	20	25	30	15	20	25
23	50	75	100	25	50	75	20	35	50	15	25	40	10	20	30

**Table F-6: Round 2 Data from 23 Participants (Most Complex Projects)**

Round 2 Data	Most Complex (Major) Projects											
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2		
Yrs from letting	10 to 20			5 to 10			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	44	74	118	34	55	92	16	28	44	12	20	32
2	40	40	40	40	40	40	20	20	20	5	5	5
3	100	200	400	50	100	200	20	40	80	10	20	40
4	30	35	50	25	25	25	15	15	15	5	10	15
5	25	30	40	15	25	35	12	20	30	10	20	25
6	25	40	50	25	25	40	10	15	25	5	10	15
7	50	75	100	30	55	90	20	35	50	12	21	33
8	30	50	100	25	50	75	10	25	40	5	15	25
9	44	74	118	34	55	92	21	34	49	12	21	33
10	40	60	150	30	50	80	15	25	40	10	15	30
11	5	40	74	5	30	55	5	25	34	5	20	21
12	50	70	100	40	60	80	20	30	40	5	10	15
13	35	45	50	25	30	35	15	20	25	10	15	20
14	40	55	60	35	45	50	30	40	45	20	30	35
15	100	200	350	100	200	300	40	50	75	20	35	70
16	25	35	40	15	25	30	10	15	20	7	10	15
17	30	40	50	25	32	45	15	20	28	7	10	16
18	70	85	100	40	55	70	20	30	40	10	20	30
19	50	100	200	35	75	100	20	35	50	10	20	30
20	100	200	400	80	160	320	60	120	240	40	80	160
21	25	50	100	25	35	75	20	25	50	10	15	25
22	50	70	110	50	70	85	40	50	70	30	40	60
23	75	100	125	50	75	100	20	40	60	20	35	50



**Table F-7: Round 3 Data from 23 Participants (Non Complex Projects)**

Round 3 Data	Non Complex (Minor) Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	23	41	67	21	34	54	16	25	38	10	17	25	5	9	15
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	50	100	200	35	70	150	25	50	100	15	30	60	5	10	20
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	15	25	30	12	20	25	10	15	20	6	12	17	5	10	15
6	20	25	35	15	20	30	10	15	25	5	10	20	0	5	15
7	23	41	67	21	34	54	16	25	34	10	17	25	5	9	15
8	0	0	0	0	0	0	10	20	30	5	10	20	0	5	10
9	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
10	15	25	40	15	25	40	10	15	30	5	12	25	5	8	15
11	5	25	38	5	20	33	5	15	23	5	10	15	5	8	10
12	25	35	55	20	30	45	15	20	30	8	10	12	3	5	7
13	20	25	30	20	25	30	15	18	20	8	12	15	3	6	8
14	30	45	60	30	35	45	25	30	35	20	25	30	10	15	20
15	40	100	200	40	100	200	40	50	100	20	35	50	10	15	20
16	20	30	40	15	20	25	10	10	15	5	8	10	5	5	5
17	18	23	30	15	20	30	11	17	22	9	12	15	4	7	12
18	25	40	60	20	35	50	15	25	35	10	15	25	8	10	15
19	25	40	100	20	35	50	15	25	35	10	15	25	5	8	15
20	50	100	200	40	80	160	30	60	100	20	30	60	10	20	30
21	25	35	50	25	25	50	10	15	25	10	15	20	5	10	10
22	20	40	60	20	40	60	10	30	40	10	20	25	10	15	20
23	25	50	75	25	40	60	20	35	50	10	15	25	5	10	15

**Table F-8: Round 3 Data from 23 Participants (Moderately Complex Projects)**

Round 3 Data	Moderately Complex Projects														
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2			Design 3		
Yrs from letting	10 to 20			5 to 10			4 or less			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	32	59	93	26	43	69	20	32	51	14	22	33	8	13	21
2	25	25	25	25	25	25	20	20	20	20	20	20	5	5	5
3	70	150	300	40	80	150	30	60	120	15	35	70	5	15	30
4	30	35	50	25	25	25	20	20	20	15	15	15	5	10	15
5	20	25	35	20	25	30	15	20	25	10	15	20	7	15	20
6	25	35	50	20	25	40	15	20	25	10	15	20	5	10	15
7	32	59	90	26	43	69	20	32	50	14	22	33	8	14	21
8	0	0	0	20	40	60	15	25	40	10	20	30	5	10	15
9	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
10	25	40	55	25	35	50	15	25	40	10	20	30	5	10	20
11	10	25	60	8	20	50	6	15	40	4	10	30	2	5	20
12	30	55	80	25	35	60	20	30	40	10	15	20	6	10	15
13	30	35	40	20	25	35	15	20	25	10	15	20	7	8	10
14	40	50	60	35	40	45	25	35	40	20	25	30	15	20	25
15	40	200	300	40	100	200	40	75	150	40	50	60	20	30	50
16	20	30	40	20	30	35	15	20	30	10	15	20	5	7	10
17	25	30	40	20	25	30	15	20	25	11	16	21	7	10	14
18	50	70	90	30	45	60	20	35	50	15	25	35	10	15	20
19	30	75	125	25	50	100	20	30	50	10	20	30	5	10	20
20	80	120	240	60	100	180	50	70	120	40	50	80	10	20	30
21	35	50	75	25	35	50	20	25	35	15	20	25	7	10	15
22	30	50	80	30	40	70	20	30	50	20	25	30	15	20	25
23	50	75	100	25	50	75	20	35	50	15	25	40	10	20	30

**Table F-9: Round 3 Data from 23 Participants (Most Complex Projects)**

Round 3 Data	Most Complex (Major) Projects											
Phase of PD	Planning			Programming/ Preliminary Design			Design 1			Design 2		
Yrs from letting	10 to 20			5 to 10			less than 4			less than 4		
Participant	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
1	47	77	127	36	60	92	21	33	51	12	22	35
2	40	40	40	40	40	40	20	20	20	5	5	5
3	100	200	400	50	100	200	20	40	80	10	20	40
4	30	35	50	25	25	25	15	15	15	5	10	15
5	25	30	40	15	25	35	12	20	30	10	20	25
6	30	40	50	25	30	40	15	25	30	10	15	25
7	50	75	120	35	60	90	21	35	50	12	22	35
8	30	50	100	25	50	75	10	25	40	5	15	25
9	44	74	118	34	55	92	21	34	49	12	21	33
10	40	60	150	30	50	80	15	25	40	10	15	30
11	20	40	100	15	30	75	10	25	50	5	20	30
12	50	70	100	40	60	80	20	30	40	10	18	25
13	35	45	50	25	30	35	15	20	25	10	15	20
14	40	55	60	35	45	50	30	40	45	20	30	35
15	100	200	350	100	200	300	40	50	75	20	35	70
16	25	35	40	15	25	30	10	15	20	7	10	15
17	30	40	50	25	32	45	15	20	28	7	10	16
18	60	85	110	40	65	90	20	35	50	10	20	35
19	50	100	200	35	75	100	20	35	50	10	20	30
20	80	160	260	60	120	200	40	60	120	20	40	60
21	25	50	100	25	35	75	20	25	50	10	15	25
22	50	70	130	50	70	90	40	50	75	30	40	60
23	75	100	125	50	75	100	20	40	60	20	35	50

**APPENDIX G**  
**COMPARISON OF SUMMARY STATISTICS, ROUND 1 VERSUS ROUND 2**

Project Type	Statistic	Round	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
			MEANS														
Non Complex	Mean	Round 1	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
		Round 2	23	41	67	21	34	54	16	25	38	10	17	25	5	9	15
Moderately Complex	Mean	Round 1	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
		Round 2	32	59	93	26	43	69	20	32	51	14	22	33	8	13	21
Most Complex	Mean	Round 1	44	74	118	34	55	92	21	34	49	12	21	33			
		Round 2	47	77	127	36	60	92	21	33	51	12	22	35			
			MEDIANs														
Non Complex	Median	Round 1	15	25	30	20	25	28	10	18	20	8	12	15	5	8	10
		Round 2	22	35	50	20	30	40	14	20	30	9	15	20	5	8	14
Moderately Complex	Median	Round 1	25	30	50	20	25	40	15	20	25	10	15	20	5	10	15
		Round 2	30	50	75	25	40	60	20	30	40	13	20	30	7	10	19
Most Complex	Median	Round 1	30	45	50	25	35	45	15	20	30	7	10	20			
		Round 2	40	60	100	34	50	75	20	28	40	10	20	30			
			STANDARD DEVIATION														
Non Complex	Standard deviation	Round 1	15	29	61	13	25	51	10	15	32	7	10	18	4	6	11
		Round 2	12	26	56	10	22	48	9	13	29	6	9	17	3	5	11
Moderately Complex	Standard deviation	Round 1	24	54	95	20	41	66	12	22	46	10	15	27	6	8	14
		Round 2	18	47	87	11	25	55	9	18	42	8	12	23	5	7	13
Most Complex	Standard deviation	Round 1	29	65	134	26	50	116	18	31	52	12	22	36			
		Round 2	26	53	109	21	43	78	12	22	45	9	16	31			

Project Type	Statistic	Round	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
			Range														
Non Complex	Range	Round 1	50	100	200	50	90	188	40	52	110	25	35	74	15	20	46
	High		50	100	200	50	100	200	40	60	120	25	40	80	15	20	50
	Low		0	0	0	0	10	12	0	8	10	0	5	6	0	0	4
	Range	Round 2	50	100	200	40	100	200	40	50	105	20	35	70	10	20	45
	High		50	100	200	40	100	200	40	60	120	20	40	80	10	20	50
	Low		0	0	0	0	0	0	0	10	15	0	5	10	0	0	5
Moderately Complex	Range	Round 1	100	200	300	100	140	220	50	80	168	40	55	112	20	28	55
	High		100	200	300	100	150	240	50	90	180	40	60	120	20	30	60
	Low		0	0	0	0	10	20	0	10	12	0	5	8	0	2	5
	Range	Round 2	75	200	300	60	100	215	45	75	160	40	50	105	20	25	55
	High		75	200	300	60	120	240	45	90	180	40	60	120	20	30	60
	Low		0	0	0	0	20	25	0	15	20	0	10	15	0	5	5
Most Complex	Range	Round 1	100	230	465	100	185	475	75	115	225	50	75	155			
	High		100	250	500	100	200	500	75	125	240	50	80	160			
	Low		0	20	35	0	15	25	0	10	15	0	5	5			
	Range	Round 2	95	170	360	95	175	295	55	105	225	35	75	155			
	High		100	200	400	100	200	320	60	120	240	40	80	160			
	Low		5	30	40	5	25	25	5	15	15	5	5	5			

**APPENDIX H**  
**PARTICIPANTS' COMMENTS, ROUND 2 QUERY**

**Table H-1: Participants' Comments (Round 2)**

Each block of comments was received from one participant, comments were received from eighteen participants in total.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
<u>1</u>	Non Complex	Programming	5 - 15%	8	10	12	20	33	51	20	30	40	Still need to identify work units & quantities - but still no major risks except inflation
		Design	40 - 70%	4	5	6	9	15	22	8	10	12	More confident with work units & quantities - basic design
		Design	70 - 100%	2	3	4	5	8	14	3	5	7	Based on dollar amount of contract
	Most Complex	Planning	7 - 15%	25	35	45	44	74	118	50	70	100	Many undefined risks at this stage for all areas of project, which I hadn't dug into in round 1.
		Programming	15 - 35%	20	25	30	34	55	92	40	60	80	Identified alternative - still have many environmental, utility, structural & stakeholder issues to consider.
		Design	75 - 100%	3	5	8	12	21	33	5	10	15	Have identified major risks, work units & quantities.
<u>2</u>	Non Complex	Planning	1 - 3%	20	40	60	22	38	60	20	40	60	Still believe for all of these that are more than a year from letting the it is the external market which the estimator cannot predict that drives the contingency.
		Design	15 - 40%	10	30	40	14	23	34	10	30	40	With less of a time interval I begin to have some comfort.
		Design	40 - 70%	10	20	30	9	15	22	10	15	25	It is time not present design that is driving the risk for these projects.
<u>3</u>	Non Complex	Design	70 - 100%	5	10	10	5	8	14	5	9	12	Construction supplements add a minimum of 5%
	Moderately Complex	Design	70 - 100%	5	10	12	7	12	19	7	14	20	Construction supplements add a minimum of 5-10%
	Most Complex	Design	75 - 100%	10	20	30	12	21	33	12	21	33	Construction supplements add a minimum of 10%



Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
<u>4</u>	Non Complex	Planning	1 - 3%	15	25	25	22	38	60	15	25	30	Increased high percentage to ensure "bracket" around long term inflation 10-20 years.
	Moderately Complex	Planning	4 - 7%	15	25	30	31	56	87	20	30	35	Increased all percentages to ensure long term inflation 10-20 years is included.
<u>5</u>	Non Complex	Planning (right through till design 40 - 70%)	1 - 3%	25	25	25	22	38	60	25	25	25	includes 5% construction contingency. I don't agree with contingencies over 50%, what is the point of doing an estimate?
	Moderately Complex	Planning (right through till design 40 - 70%)	4 - 7%	20	20	20	14	23	34	20	20	20	includes 5% construction contingency
	Most Complex	Planning (right through till design 35 - 75%)	7 - 15%	20	20	20	9	15	22	20	20	20	includes 5% construction contingency
<u>6</u>	Non Complex	Programming	5 - 15%	25	25	25	20	33	51	25	25	35	All of these percentages are based on what I have seen from various studies.
		Design	70 - 100%	5	10	10	5	8	14	5	10	10	Construction Congtingency of up to 5%.
	Moderately Complex	Design	70 - 100%	5	10	15	7	12	19	7	10	15	Construction Contingency of 5 to 7%.
	Most Complex	Design	75 - 100%	5	7	10	12	21	33	10	15	25	Construction Contingency of 5 to 10%.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
Z	Non Complex	Planning	1 - 3%	15	20	25	22	38	60	18	23	30	For all items on all lists: 1- I suggest that the averages from Round 1 are skewed because of some very high estimates. I found much better correlation with the median values. 2 - I still sense some confusion about if inflation is included in contingency. I assumed that inflation (and most inflation risk) is handled by a separate line item and is NOT included in these values. I suggest that further clarification on this issue may help us more easily come to a consensus.
		Programming	5 - 15%	13	15	20	20	33	51	15	20	30	For maintenance and overlay projects at concept development, our agency's guidelines for contingency are 10% for rural projects or 15% for urban projects. This is in addition to the 5-10% change order contingency required to advertise the project.
		Design	70 - 100%	3	5	10	5	8	14	4	7	12	Our agency's required change order contingency to advertise the project is 5-10%
	Moderately Complex	Programming	15 - 25%	15	20	25	27	44	66	20	25	30	At concept development, our agency's loose guidelines for contingency are about 15%. This is in addition to the 10% change order contingency required to advertise the project.
		Design	70 - 100%	6	8	12	7	12	19	7	10	14	Our agency's required change order contingency to advertise the project is 10%.
	Most Complex	Programming	15 - 35%	20	25	30	34	55	92	25	32	45	At concept development, our agency's loose guidelines for contingency are about 20%. This is in addition to the 10% change order contingency required to advertise the project.
		Design	75 - 100%	7	10	15	12	21	33	7	10	16	Our agency's required change order contingency to advertise the project is 10%.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
<u>8</u>	Non Complex	Planning	1 - 3%	40	100	200	22	38	60	40	100	200	Non-complex jobs tend to be intensive commodity, lower labor project sectors (preservation in particular). Parametric basis is stable but intensive to commodity pricing. Extreme volatility in energy and oil based on relatively fixed known reserves will continue to push higher ranges of risk on the high side of risk distribution
		Programming	5 - 15%	40	100	200	20	33	51	40	100	200	Non-complex jobs tend to be intensive commodity, lower labor project sectors (preservation in particular). Historic basis is market driven and more reactive to volatility but most preliminary work is scoped on off season - at lower commodity basis prices and tends to level out with 5-10 year time basis. Contingencies tend to be similar to parametric basis
		Design	15 - 40%	40	50	100	14	23	34	40	50	100	Commodity risk horizons are shortened to under 2 years, leaving prices subject to world market demands - top end risk is reduced but median risk remains (price risk predominates and aggravates lack of quantity accuracy).
		Design	40 - 70%	20	35	50	9	15	22	20	35	50	Increases in accuracy reduct top end risk but 4 year window is double the prediction event horizon of 2 years for commodity markets - subject to high volatility.
		Design	70 - 100%	10	20	50	5	8	14				Further accuracy under both bid and cost base bids reduce bottom end risk but 4 year window maintains high end risk due to 2 year commodity event horizon.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
	Moderately Complex	Planning	4 - 7%	40	200	300	31	56	87	40	200	300	No change to compound risk problem with both quantities and commodity prices. There is some reduction in risk composite towards labor away from commodities - offset by level of definition.
		Programming	15 - 25%	40	150	200	27	44	66	40	100	150	reconsideration - due to composite reduction of commodity influence. 2 year commodity event horizon still a heavy influence.
		Design	25 - 35%	40	75	150	19	30	46	40	75	150	reconsideration - due to composite reduction of commodity influence. 2 year commodity event horizon still a heavy influence.
		Design	35 - 70%	40	50	60	13	21	30	40	50	60	2 year horizon with high volatility is primary cost driver on upper end scale.
		Design	70 - 100%	20	30	50	7	12	19	20	30	50	2 year horizon with high volatility is primary cost driver on upper end scale.
	Most Complex	Planning	7 - 15%	100	250	500	44	74	118	100	200	350	reconsidered based on latest market information of labor influence to risk pricing (market deflation of wages and reduced commodity influence on this work type.
		Programming	15 - 35%	100	200	500	34	55	92	100	200	300	reconsidered based on latest market information of labor influence to risk pricing (market deflation of wages and reduced commodity influence on this work type. Higher upper band risk remains due to 2 year market event horizon
		Design	35 - 75%	40	60	75	21	34	49	40	50	75	2 year horizon with high volatility is primary cost driver on upper end scale.
		Design	75 - 100%	20	50	70	12	21	33	20	35	70	2 year horizon with high volatility is primary cost driver on upper end scale.
<u>9</u>	Non Complex	Design	70 - 100%	4	8	12	5	8	14	4	8	12	Policy automatically allow for 5% contingency, approval of Chief Engineer is required when a contingency other then 5% is used.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
	Moderately Complex	Design	70 - 100%	8	12	20	7	12	19	8	12	20	Policy automatically allow for 5% contingency, approval of Chief Engineer is required when a contingency other than 5% is used.
	Most Complex	Design	75 - 100%	12	20	32	12	21	33	12	20	32	Policy automatically allow for 5% contingency, approval of Chief Engineer is required when a contingency other than 5% is used.

<u>10</u>	Non Complex	Planning	1 - 3%	10	15	20	22	38	60	15	25	40	Most non-complex projects are planned less than 10 years (realistically more like <5 years) before construction. These are typically pavement preservation and safety projects.
		Programming	5 - 15%	8	12	20	20	33	51	15	25	40	Parametric estimating is most likely used for pavement preservation at this stage. Construction risks are low.
		Design	15 - 40%	5	8	15	14	23	34	10	15	30	Unknowns are unlikely; quantities are the biggest uncertainty.
		Design	40 - 70%	3	5	10	9	15	22	5	12	25	Most of the bid items are quantified, but quantities could be off.
		Design	70 - 100%	0	3	5	5	8	14	5	8	15	Biggest risk is that quantities are off.
	Moderately Complex	Planning	4 - 7%	20	30	40	31	56	87	25	40	55	Scope may not be correct; high potential for unknowns and construction risk
		Programming	15 - 25%	20	25	30	27	44	66	25	35	50	Scope may be off, quantities can change, unknown conditions may not be identified yet, schedule can slip because of environmental factors or staffing issues.
		Design	25 - 35%	10	18	25	19	30	46	15	25	40	Scope should be set. Quantities can be off; potential for some unknown conditions; schedule can slip.
		Design	35 - 70%	5	12	15	13	21	30	10	20	30	Still a potential for some unknown conditions; schedule can slip

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
	Most Complex	Planning	7 - 15%	25	40	50	44	74	118	40	60	150	Site conditions, public involvement and environmental process can result in changed scope; high potential for unknowns and schedule risks.
		Programming	15 - 35%	20	25	35	34	55	92	30	50	80	Scope could change, still have potential for unknowns and schedule risks.
		Design	35 - 75%	10	15	20	21	34	49	15	25	40	80% of the items are quantified, scope is set. Still a potential for unknowns during design or construction. Schedule still at risk.
		Design	75 - 100%	3	10	15	12	21	33	10	15	30	Biggest risks are schedule slipping (right-of-way, utilities) and construction unknowns.
<u>11</u>	Non Complex	Planning	1 - 3%	0	10	25	22	38	60	0	25	38	I still think 0 is a valid contingency. We redo our estimates each year, adding items such as walls, turn lanes, etc. to our perlane mile costs. If we didn't have the time to do detailed early estimates, I would use a higher contingency also.
		Programming	5 - 15%	0	10	20	20	33	51	0	20	33	I think the danger of having too high of a contingency is that you could easily not have enough projects produced to build in a year.
		Design	15 - 40%	0	10	15	14	23	34	0	15	23	Our overall construction contingency for change orders, etc. is 3% for all projects.
	Most Complex	Planning	7 - 15%	0	20	40	44	74	118	5	40	74	I would grant that on complex projects, there are all sorts of influences that change the design and price. So I would be fine with higher contingencies.
<u>12</u>	Non Complex	Planning	1 - 3%	50	100	200	22	38	60	50	100	200	I stand by my original estimates - 10 to 20 years from letting is a long time - scopes and projects are long from settled

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
		Programming	5 - 15%	40	80	160	20	33	51	40	80	160	I stand by my original estimates - 5 to 10 years from letting is a long time - scopes and projects are long from settled
		Design	15 - 40%	30	60	120	14	23	34	30	60	120	I stand by my original estimates - 15% to 40% level of definition means 60% to 85% is yet to be defined - much can happen.
		Design	40 - 70%	20	40	80	9	15	22	20	40	80	I stand by my original estimates - 40% to 70% level of definition means 30% to 60% is yet to be defined - much can happen.
		Design	70 - 100%	10	20	40	5	8	14	10	20	40	I stand by my original estimates HOWEVER the caveat I offer is: upon 100% design 10% is the more appropriate figure for contingency (the 20-40% is when you are still closer to only 70% design). NOTE: This agency requires a 4% change order contingency after contract is awarded.
	Moderately Complex	Design	70 - 100%	15	30	60	7	12	19	15	30	60	I stand by my figures for same reasons as above - HOWEVER I offer this caveat: as a project approaches 100% design, a construction risk register and strategies can be developed - making contingency more likely in the 10% to 20% range - and it can be in the form of a risk reserve. NOTE: This agency requires a 4% change order contingency after contract is awarded.
	Most Complex	Design	75 - 100%	40	80	160	12	21	33	40	80	160	I stand by my figures for same reasons as above - HOWEVER I offer this caveat: as a project approaches 100% design, a construction risk register and strategies can be developed - making contingency more likely in the 10% to 20% range - and it can be in the form of a risk reserve. NOTE: This agency requires a 4% change order contingency after contract is awarded.

Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
<u>13</u>	Non Complex	Planning	1 - 3%	50	100	200	22	38	60	50	100	200	I have not changed my scores, which seem to be at the high end among the respondents As this estimate is 10 to 20 years from letting, I would be uncomfortable with a smaller contingency.
		Programming (Comment applies to all phases, and all project types)	5 - 15%	35	70	150	20	33	51	35	70	150	I have not changed my scores, which seem to be at the high end among the respondents. Nevertheless, it seems to me that my numbers reflect the uncertainties in the industry and the nature of our long-term projects.
<u>14</u>	Non Complex	Planning	1 - 3%	30	35	50	22	38	60	30	35	50	These comments apply to all projects: Initiating Functional Units (Maintenance, Traffic, and Planning) typically develop a feasibility study (conceptual Report) which defines the initial project scope.
		Programming	5 - 15%	25	25	25	20	33	51	25	25	25	Each estimate also includes 5-10% for Minor Items and 5% for Supplemental Work that cannot be identified at the time of the estimate except for Plans, Specifications, & Estimate. These items of work must be quantified in the final estimate.
		Design	40 - 70%	15	15	15	9	15	22	15	15	15	The estimates are updated at least annually between these Project Development milestones. Estimates are also updated when additional information becomes available (e.g. hazard waste reports, geotechnical reports, etc).
		Design	70 - 100%	5	10	15	5	8	14	5	10	15	Contingency is a reflection of level of confidence. As a project is developed, the number of unknowns is reduced. At 100% we are required to have the contingency level at 5%.
<u>15</u>	Non Complex	Planning	1 - 3%	10	25	40	22	38	60	NA	NA	NA	I agree with previous comment that these type projects very rarely go beyond 3-5 yrs



Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
		Programming	5 - 15%	10	20	30	20	33	51	NA	NA	NA	I agree with previous comment that these type projects very rarely go beyond 3-5 yrs
	Moderately Complex	Planning	4 - 7%	10	30	50	31	56	87	NA	NA	NA	Projects likely do not go beyond 10 yrs

<u>16</u>	Non Complex	Planning (Comment applies to all planning phases - Moderately and Most Complex project types)	1 - 3%	50	75	100	22	38	60	25	50	75	For all responses: The Delphi Method requires that each respondent have a clear and common definition of what's being assessed. I see that for Round 2 you've attempted to do this by refining "Contingency" as follows: 1) limit it to the scope to be included in the Engineer's Estimate; and 2) exclude a few categories of costs (ref: note on Tab (1)). Limiting the contingency to the scope in the Engineer's Estimate excludes most of the uncertainty in project scope/design alternative (i.e., those decisions have been resolved by the time the Engineer's Estimate is made). These major project uncertainties accounted for a significant portion of my original response values. Excluding this design alternative / scope uncertainty from the estimating process is not desirable because: 1) the scope uncertainties are very real and must be considered in project budgeting and programming from the project's inception; and 2) it allows the project 'baseline' to continue to be redefined all the way until the Engineer's Estimate is made, which provides a misleading history of cost growth. The other items you've specifically excluded do influence uncertainty in construction contingency; however, a number of issues that you specifically did not exclude could still "drive" construction cost uncertainty (and, therefore, contingency). These include (for example) uncertain construction market conditions and commodity prices, uncertain cost inflation rates, and uncertainty in overall project schedule (what happens before construction influences
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Participant	Project Type	Project Phase	Level of Definition	Low	MLE	High	Low	MLE	High	Low	MLE	High	Comments
													YOE construction cost). Despite my reservations about the exclusions you've made for Round 2, my revised responses attempt to honor your intent (i.e., exclude scope uncertainty prior to the Engineer's Estimate; exclude uncertainty in 'soft costs' and ROW; include other significant risks).
	Most Complex	Design	75 - 100%	50	75	100	12	21	33	20	35	50	Market conditions risk!
<u>17</u>	Non Complex	Planning (Comment applies to all phases, and all project types)	1 - 3%	35	50	60	22	38	60	30	45	60	15% is added to construction estimate to cover CEI and contingencies
<u>18</u>	Most Complex	Planning	7 - 15%	50	125	200	44	74	118	50	100	200	Early in the planning phase it is very difficult to limit the higher range of contingency risk on a project.

**APPENDIX J**  
**COMPARISON OF SUMMARY STATISTICS FOR ROUNDS 1, 2 AND 3**

### Comparison of Rounds 1, 2, and 3 Means and Medians

ROUND	PROJECT TYPE	STATISTIC	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Round 1	Non Complex	Mean	22	38	60	20	33	51	14	23	34	9	15	22	5	8	14
Round 2	Non Complex	Mean	23	41	67	21	34	54	16	25	38	10	17	25	5	9	15
Round 3	Non Complex	Mean	24	41	68	21	34	56	16	25	38	11	17	25	5	9	14
Round 1	Moderately Complex	Mean	31	56	87	27	44	66	19	30	46	13	21	30	7	12	19
Round 2	Moderately Complex	Mean	32	59	93	26	43	69	20	32	51	14	22	33	8	13	21
Round 3	Moderately Complex	Mean	33	59	92	27	43	68	21	31	50	15	22	32	8	13	20
Round 1	Most Complex	Mean	44	74	118	34	55	92	21	34	49	12	21	33			
Round 2	Most Complex	Mean	47	77	127	36	60	92	21	33	51	12	22	35			
Round 3	Most Complex	Mean	47	75	125	36	59	89	20	31	48	12	21	32			

Round 1	Non Complex	Median	15	25	30	20	25	28	10	18	20	8	12	15	5	8	10
Round 2	Non Complex	Median	22	35	50	20	30	40	14	20	30	9	15	20	5	8	14
Round 3	Non Complex	Median	23	35	55	20	30	45	15	20	30	10	15	22	5	9	15
Round 1	Moderately Complex	Median	25	30	50	20	25	40	15	20	25	10	15	20	5	10	15
Round 2	Moderately Complex	Median	30	50	75	25	40	60	20	30	40	13	20	30	7	10	19
Round 3	Moderately Complex	Median	30	50	75	25	40	60	20	30	40	14	20	30	7	10	20
Round 1	Most Complex	Median	30	45	50	25	35	45	15	20	30	7	10	20			
Round 2	Most Complex	Median	40	60	100	34	50	75	20	28	40	10	20	30			
Round 3	Most Complex	Median	40	60	100	35	50	80	20	30	49	10	20	30			

### Comparison of Rounds 1, 2, and 3 Data Ranges

ROUND	PROJECT TYPE	STATISTIC	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Round 1	Non Complex	Range	50	100	200	50	90	188	40	52	110	25	35	74	15	20	46
		High end of range	50	100	200	50	100	200	40	60	120	25	40	80	15	20	50
		Low end of range	0	0	0	0	10	12	0	8	10	0	5	6	0	0	4
Round 2	Non Complex	Range	50	100	200	40	100	200	40	50	105	20	35	70	10	20	45
		High end of range	50	100	200	40	100	200	40	60	120	20	40	80	10	20	50
		Low end of range	0	0	0	0	0	0	0	10	15	0	5	10	0	0	5
Round 3	Non Complex	Range	50	100	200	40	100	200	35	50	85	15	27	50	10	15	25
		High end of range	50	100	200	40	100	200	40	60	100	20	35	60	10	20	30
		Low end of range	0	0	0	0	0	0	5	10	15	5	8	10	0	5	5
Round 1	Moderately Complex	Range	100	200	300	100	140	220	50	80	168	40	55	112	20	28	55
		High end of range	100	200	300	100	150	240	50	90	180	40	60	120	20	30	60
		Low end of range	0	0	0	0	10	20	0	10	12	0	5	8	0	2	5
Round 2	Moderately Complex	Range	75	200	300	60	100	215	45	75	160	40	50	105	20	25	55
		High end of range	75	200	300	60	120	240	45	90	180	40	60	120	20	30	60
		Low end of range	0	0	0	0	20	25	0	15	20	0	10	15	0	5	5
Round 3	Moderately Complex	Range	80	200	300	52	80	175	44	60	130	36	40	65	18	25	45
		High end of range	80	200	300	60	100	200	50	75	150	40	50	80	20	30	50
		Low end of range	0	0	0	8	20	25	6	15	20	4	10	15	2	5	5
Round 1	Most Complex	Range	100	230	465	100	185	475	75	115	225	50	75	155			
		High end of range	100	250	500	100	200	500	75	125	240	50	80	160			
		Low end of range	0	20	35	0	15	25	0	10	15	0	5	5			
Round 2	Most Complex	Range	95	170	360	95	175	295	55	105	225	35	75	155			
		High end of range	100	200	400	100	200	320	60	120	240	40	80	160			
		Low end of range	5	30	40	5	25	25	5	15	15	5	5	5			
Round 3	Most Complex	Range	80	170	360	85	175	275	30	45	105	25	35	65			
		High end of range	100	200	400	100	200	300	40	60	120	30	40	70			
		Low end of range	20	30	40	15	25	25	10	15	15	5	5	5			

### Comparison of Rounds 1, 2, and 3 Standard deviations

ROUND	PROJECT TYPE	STATISTIC	Planning			Programming			Design 1			Design 2			Design 3		
			Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High	Low	MLE	High
Round 1	Non Complex	Standard deviation	15	29	61	13	25	51	10	15	32	7	10	18	4	6	11
Round 2	Non Complex	Standard deviation	12	26	56	10	22	48	9	13	29	6	9	17	3	5	11
Round 3	Non Complex	Standard deviation	11	26	56	10	22	48	8	13	26	5	7	14	3	4	6
Round 1	Moderately Complex	Standard deviation	24	54	95	20	41	66	12	22	46	10	15	27	6	8	14
Round 2	Moderately Complex	Standard deviation	18	47	87	11	25	55	9	18	42	8	12	23	5	7	13
Round 3	Moderately Complex	Standard deviation	17	44	80	10	22	47	9	16	34	9	10	16	4	6	9
Round 1	Most Complex	Standard deviation	29	65	134	26	50	116	18	31	52	12	22	36			
Round 2	Most Complex	Standard deviation	26	53	109	21	43	78	12	22	45	9	16	31			
Round 3	Most Complex	Standard deviation	23	49	96	18	39	65	9	12	24	6	10	16			

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